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MR. JOS. M. WILSON, President, in the chair.

THE FIRE-RETARDING QUALITIES OF WIRED-GLASS.

BY CHAS. A. HEXAMER, C. E.,

Member of the Institute, Secretary of the Philadelphia Fire-Underwriters' Association.

On November 1, 1893, the Committee of Science and the Arts of the Franklin Institute adopted a report recommending the award, to Frank Shuman, of the John Scott Legacy Premium and Medal, for his machine and process for producing wired-glass. This report, at some length, discusses the varied uses to which wired-glass can be put, and its superiority in numerous applications over the ordinary glass. The question of the fire-retarding qualities of the

wired-glass, however, was passed over without special comment.

In the autumn of 1893, my attention was called to some fire-doors in the large establishment of the J. B. Stetson Company, of this city. These doors, which were provided for the purpose of protecting the opening in each story to a brick elevator-shaft, had a large sheet of wired-glass inserted as a transparent panel. The manager of the factory, Mr. Theo. C. Search, had made a number of fire tests of wired-glass, and, as a result, had come to the conclusion that the material would answer as a fire-retardent. The writer is of the opinion that the case cited is the first instance of using wired-glass for this purpose, although, as stated in the report of the Committee of Science and the Arts, the first patent for wired-glass was granted in 1855, to an Englishman named Newton, for "a fire-proof and burglar-proof glass."

In December of the year 1893, Mr. W. S. Lemmon, Inspector of the Newark (N. J.) Committee of the Underwriters' Association of the Middle Department, requested an owner in that city to place wired-glass in two windows of his warehouse, to protect it from external exposure. This resulted in a test of the fire-retarding quality of wired-glass in Newark, which is described by Mr. Lemmon, in a letter, as follows:

"A small brick building, about 6 x 10 feet, was built, in which were placed the following windows, all glazed with wired-glass, $\frac{1}{4}$ inch in thickness: one 20 x 80 inches, one 28 x 80 inches and one 30 x 80 inches. In the building, a fire was made for half an hour, a high degree of heat being developed. When the glass became red hot, cold water was turned on by the city Fire Department, under 60 pounds pressure, through the regular fire hose. In addition to the throwing of water on the glass, the chief of the Fire Department tried, without success, to throw a half brick through the glass while it was red hot; this was to show the result of falling walls against the glass when in actual use for exposure purposes."

In this test, the frames holding the wired-glass in place

were constructed of angle iron and of galvanized sheet-iron. The intense heat warped and bent the metal work, but the glass did not fall out on account of the warping. Mr. Lemmon further reports that since December, 1893, nearly eighty windows in his city had been constructed of wired-glass, in metal frames, to protect buildings against outside exposure, and in a number of cases actual fire tests proved the value of the wired-glass for the purpose designated.

FIG. 1.

In our own city, besides being used in a number of fire-doors in stairway- and elevator-shafts, wired-glass partitions have been erected in a number of buildings.

At the request of the Mississippi Glass Company, which controls the manufacture of wired-glass, the writer, in conjunction with Inspector Wm. McDevitt, made a series of tests of the fire resisting qualities of wired-glass, the main test being described in the following report made to the Committee of the Philadelphia Fire Underwriters' Association:

REPORT ON TEST OF THE FIRE-RESISTING QUALITY OF WIRED-GLASS.

A brick test-house, about 3 x 4 feet, inside measurement, and 9 feet high, was constructed in the yard of the Pennsylvania Iron Works, near Fiftieth Street and Merion Avenue. In one side of this structure a wired-glass window was fastened in a wooden frame, covered with lock-jointed tin. In another side, a Philadelphia standard fire-door was hung. The upper part of this door had a pane of wired-glass, 18 x 24 inches, set into a wooden metal-covered frame. The entire roof of the test-house was replaced by a sky-light, the sash being constructed of wood, metal-covered; one side of this skylight being provided with three lights of ¼-inch ordinary rough glass, the

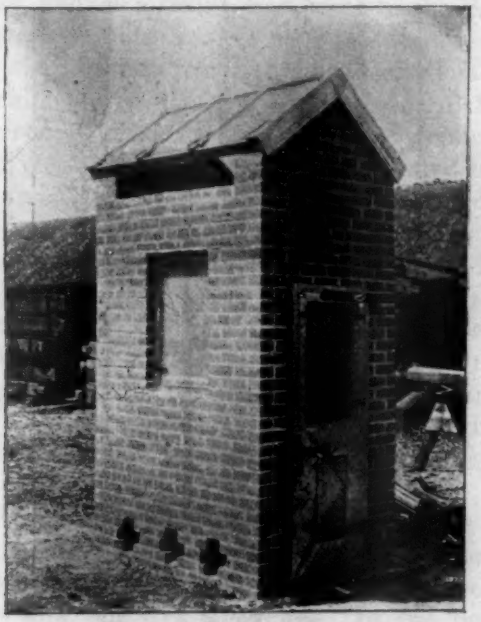

FIG. 2.

other side with three lights of wired-glass. The entire structure was constructed by John J. Husband, in accordance with specifications furnished by the Secretary. The wired-glass used was ¼ inch thick, and was manufactured by the Mississippi Glass Company, of St. Louis.

In order to make the fire test as severe as possible, iron grate-bars were placed in the bottom of the test-house, and openings were left in the wall near the ground for free draught. The test house was filled for two-thirds of its height with wood, approximately one-half cord being used. After treating the wood with a liberal allowance of coal oil and resin, the fire was started. In a few minutes the ordinary rough glass in the skylight cracked and pieces began to fall into the fire. The wired-glass in the fire-door soon became red

hot, so that a piece of paper held against it on the outside was easily ignited. The three plates of wired-glass in skylight, subjected to the entire heat of the fire, also became red hot, but retained their positions throughout the test. At the end of thirty minutes, water was thrown on the fire and also on the hot glass. After the fire was extinguished, the three plates of glass in the skylight were found to be cracked into countless pieces, but still adhering together, forming one sheet. The window light, which, as the result showed, was not properly secured to the frame, was found to be of same condition as skylight glass, excepting that a large crack had developed. The plate of glass in the standard fire-door was cracked, the same as the skylight; but having been

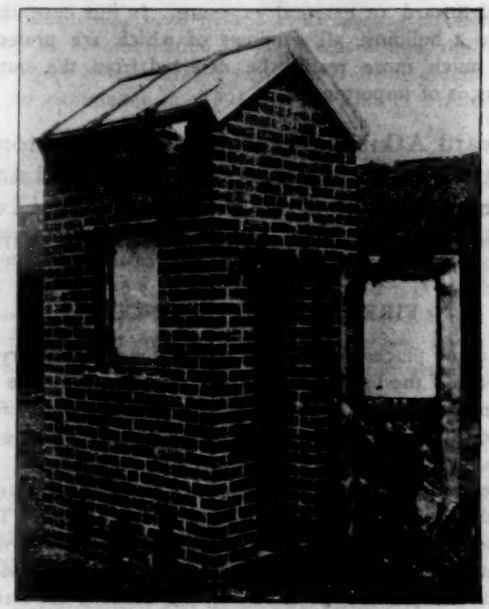

FIG. 3.

well secured into the door frame, it did not give way. The action of the fire on the wooden metal-covered skylight and window frame showed conclusively that this class of construction is far superior to iron framing, no warping or giving way of any portion of the frames being noticed. The fire-door in direct contact with the fire showed but little buckling on the inner side, and no signs of giving way. On removing the tin covering, it was found, however, that the inner layer of 1-inch boards was completely charred through, but that the second layer was only slightly damaged.

The conclusions to be drawn from the test appear to be as follows:

(1) Wired-glass can safely be used in skylights, and in such situations will withstand a severe fire and will not give way when water is thrown on it. A

wooden framing for skylight, covered with tin, all seams lock-jointed and concealed-nailed, is superior in fire-resisting quality to iron framing.

(2) Wired-glass in wooden sash, covered with tin, all seams lock-jointed and concealed-nailed, can safely be used for windows toward an external exposure.

(3) Wired-glass can safely be used in fire-doors to elevator shafts and stairway towers, where it is necessary to light said shafts.

(4) In office buildings, hotels, etc., where it is undesirable to have elevator shafts entirely enclosed and dark, wired-glass permanently built into a brick or terra-cotta shaft, or arranged in a wood metal-covered frame, can safely be used.

(5) Wired-glass plates, securely fastened in standard fire-shutters, can safely be used toward an external exposure. In this case, the fact that a possible fire in a building, all windows of which are protected by fire-shutters, can much more readily be detected from the outside through the wired-glass, is of importance.

Mr. Edward Atkinson, President of the Boston Manufacturers' Mutual Insurance Company, witnessed a test of the fire-retarding quality of wired-glass, in Boston. I quote from Circular No. 69, issued by him in April of this year, as follows:

FIRE-RETARDENT WINDOWS.

There are many places in our risks where it would be very desirable to brick up windows if the light could be spared, but where the requirements for light render it necessary to leave the spaces as they are, often protected with automatic shutters, but sometimes under such conditions that the risk must remain unguarded.

The intervention of wired-glass will, in such cases and in many others, suffice to retard the passage of fire in a fully adequate manner. This glass, originally invented for skylights, is now being applied to fire-retardent purposes. It has been introduced in some of the Western cities, around elevators, in place of the ordinary iron cages. It may be used in our risks for similar purposes.

First, it may be remarked that while, at the beginning, when used for skylights, some defects were disclosed in the differential strain on the glass and the wire under the heat of the sun, that fault is claimed to have been entirely removed. It would not affect the present purpose.

Second, a test of the fire-resisting properties of this wired-glass was witnessed by the undersigned in the vicinity of the Boston Plate Glass Company, on A Street, South Boston. What might be called an iron stove was constructed in the form of a fireplace with a wired-glass blower. It was 3 feet high, 1 foot in depth from face to back, 2 feet wide on front. It was set up on bricks, so as to give a draught all around, and was open at the top. The plate of glass which formed the blower was 18 x 34 inches. This fireplace

was filled to the top with hard wood, and resinous wood upon which kerosene oil had been poured, which was set on fire, resting in front against the glass.

The first effect was to cover the inside of the glass with soot, but after about fifteen minutes the soot was burned off, leaving the glass clear, as at the beginning. The stove was re-charged, and this intense heat affected the glass for nearly half an hour. A stream of cold water was then thrown on the glass from the outside. Presently the fire was put out with another stream and the glass was showered from within. The effect was to crack the glass into millions of pieces; but, being held by the wire, none fell out, neither did the glass spring or bend. It held its place even while the iron of the stove was twisted and bent.

This glass has already been placed at dangerous points in a few of our risks, and may be recommended in all places where the light must be retained, but where it is desirable to put in a fire-retardent material. We have as yet no experience in the test of this kind of window under actual fire.

The glass on which these tests have been made, which is intended for windows or doors, is ¼ inch thick, but it is made up to 1 inch in thickness. The ¼ inch is, of course, too heavy for the ordinary window frame, nor should any wood be used in the setting of the glass unless absolutely protected. Instructions will be given for placing it in metal frames. This glass is made up to 1 inch in thickness, and that thickness, properly supported beneath, might in many places be suitable to put into floors for the purpose of giving light in dark basements or elsewhere; of course, being placed so as not to be subjected to trucks with iron wheels or other danger of chipping.

It is clearly indicated from the above that wired-glass can safely be used as a fire-retardent in numerous ways. From personal experience, I am led to believe that metal-covered wood framing is superior to iron frames for holding the glass in place.

In closing, I would say that the capability of the wired-glass to withstand a temperature beyond the melting point of glass, appears to be attributable to the fact that the network of wire in the glass acts as a good conductor of heat, and thereby prevents the accumulation of sufficient heat to melt the glass; and although it may thereby be softened and rendered pliable, the network of wire prevents the glass from giving way by reason of its own weight when softened by the heat.

The accompanying illustrations will serve to render the preceding descriptions of tests more intelligible.

Fig. 1 shows a window of wired-glass in iron framing, built in a brick wall of a building in Newark, N. J. This window was subjected to a very severe fire, which ultimately destroyed the entire building. The photograph was taken several weeks after the fire.

Fig. 2 shows the brick test-house in the yard of the Pennsylvania Iron Works, Philadelphia, before being subjected to the fire test.

Fig. 3 shows the test-house after having been subjected to the fire test.

PANTASOTE, A NEW FABRIC.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the products manufactured by the Pantasote Leather Company, of Passaic, N. J.*]

[No. 1772.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 9, 1895.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating pantasote leather, reports as follows:

The products, called by the manufacturers "Pantasote," include fabrics of various kinds intended to serve the same uses as leather in upholstering, carriage-furnishing, bookbinding, trunk- and bag-making, mural decoration, etc.

It is made by applying a composition (of which the ingredients and mode of treatment are not disclosed), to the surface of textile fabrics of various kinds, and paper. The successive steps in the process of manufacture are described in sufficient detail to enable it to be clearly understood, in a communication furnished by the manufacturers, and which accompanies this report as an appendix.* These details, as will appear from the appendix, have been very intelligently worked out, and a plant of considerable magnitude, equipped with specially designed machinery, was

* Filed in the committee's archives.

erected in Passaic, N. J., in 1891, where the manufacture of pantasote products has since been carried on commercially.

Referring to the mode of producing pantasote goods, the composition, or "gum," as it is termed in the manufacturers' description, when applied to the surface of the fabric, becomes thoroughly incorporated with the substance of the fabric upon which it is spread, adhering so tenaciously that it cannot be detached from the finished material. The products possess in high degree the qualities of flexibility and imperviousness to moisture, and notable freedom from any tendency to develop a "stickiness," or brittleness under ordinary conditions of temperature.

They are made to take any desired color by incorporating the same with the gum before it is spread on the fabric; and any desired grain in close imitation of the appearance of alligator, seal, morocco, hog skin, etc.; and any desired pattern in relief, as in the case of embossed leather. The appearance of these counterparts, and the excellent adaptability of the pantasote products for decorative effects are seen in the accompanying specimens, and leave nothing to be desired. The mode of making these surface impressions involves the use of powerful presses, the dies for which are made by an ingenious system of casting in bronze and iron from the original tissues, devised by Mr. A. E. Outerbridge, Jr., in which the impression is obtained in iron or bronze from the skins themselves. For this purpose dies 36 inches square have been made by the method referred to.

In respect also of "body," these products present great variety, from the "single texture" goods of light weight, suitable for book-binding, linings for trunks, bags, fancy leather goods, gossamer waterproofs, etc., to heavy materials suitable for upholstering and the like, in which the "body" is made of any desired thickness by a special method (protected by letters-patent), in which the "single texture" goods are backed with paper, or with a heavy cotton fabric, the two being made to unite by running between them a layer of specially prepared gum. This serves not only the purpose of sticking the two fabrics together, but also, as the manufacturers explain, "forms an impressionable

cushion, which receives and holds the embossed pattern, which being thus impressed in a solid surface, does not flatten or press out in handling or in the wear and tear of use."

The manufacturers claim for these products that they afford, notably, an admirable substitute for leather for most of the uses to which leather is adapted, and also that they possess some desirable qualities which leather does not possess. Reference is made particularly to the durable pliability of the pantasote products, under the continued influence of extreme heat and cold, and to the indifference of the products to water, fresh or salt, and to the fact that they may be scrubbed to remove dirt or grease, thus permitting of the use of the most delicate shades of color, which, in leather, soon soil.

There appeared to the investigating committee to be only one way in which these claims could safely be verified, namely, by the test of actual service, and, accordingly, this report has been deferred until sufficient time should have elapsed to obtain from reliable parties having the material in use, their testimony as to its fitness for various requirements of service.

The investigating committee, for this purpose, has placed itself in correspondence, during the last two years, with a number of manufacturers, builders and others having these products in use, and who may be assumed to be familiar with the merits of other leather substitutes, in order to learn from them how the pantasote products have stood the test of practical service.

Replies to these inquiries have been received from manufacturers of furniture, car builders, carriage builders, boat and ship builders, and others. These replies are uniformly favorable, and indicate that, as a substitute for leather for upholstery and carriage work, the pantasote products have undoubted merit, and that for these uses it is the best substitute for leather that has thus far been placed upon the market. The investigating committee has not been able to verify the claims of the manufacturers respecting the adaptability of their products for numerous other uses; but as

the above-named industries will probably consume much the larger proportion of the material, the committee does not deem it expedient to withhold its report longer for the purpose of including therein other and less important data.

The conclusion is warranted from the foregoing statement of facts, that the products collectively known by the name of "Pantasote" constitute a highly meritorious substitute for leather, for a number of the uses for which leather is adapted.

The Franklin Institute accordingly awards to the Pantasote Leather Company, of New York, the Edward Longstreth Medal of Merit.

Adopted at the stated meeting of the Committee on Science and the Arts, held February 5, 1896.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

SAMUEL SARTAIN, *Chairman.*

THE DELANY SYSTEM OF MACHINE TELEGRAPHY.

[*Being the Report of the Committee on Science and the Arts, on the invention of Patrick B. Delany.*]

[No. 1896.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1896.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating Delany's system of machine telegraphy, finds as follows:

The United States Patents submitted by the inventor, Patrick B. Delany, Nos. 510,006, 536,420 and 541,967, describe a perforator, a transmitter and a receiver. Patents are also pending for minor details.

The system, generally described, is a method of high-speed automatic transmission by a punched ribbon of paper, which makes and breaks an electric circuit, and the reception of the impulses upon a moistened ribbon of chemically

prepared paper, which is discolored by the passage of the current through it.

Other systems have preceded it, to which this general description applies, the details of which, however, are very different from the Delany system. The speed and reliability of all so-called high-speed systems have heretofore been limited by the static charge of the conductor and magnet coils. Many devices have been patented with the object of dissipating and neutralizing this charge, chief among which are the grounding of the conductor after every impulse, the reversal of the polarity of the current at each impulse, and the insertion of condensers in the circuit; all these methods have proven helpful, but not sufficiently so to make the systems commercially successful in operating a line, say, 1,000 miles long, at a speed of over 250 words a minute. When greater speeds are attempted, the static charge of the line following after the battery impulse when the circuit is opened continues the effect and closes up the spaces between the dots, or dots and dashes.

Mr. Delany, whose long experience and whose inventions in multiplex and cable telegraphy have made him thoroughly familiar with the methods of dealing with the static charge, has, in this system, devised a method of avoiding its effects, which is at once ingenious and valuable. In all prior systems the dots and dashes of the alphabet have been received in the same line of the paper, and the dots and dashes were used as their names imply. In the system under consideration, dots only are used. The dashes of the alphabet are distinguished from the dots by being received in a different line of the paper, and by being received in duplicate lines. The message will, therefore, be received in three parallel lines on the ribbon, the dots of the alphabet occupying the center line, the two outside lines showing the dots which represent the dashes of the alphabet, the same signal appearing in both outside lines. The dots and dashes, therefore, can never run together. As all the signals are dots, if two dots in the same line should run together by the action of the static charge, the comparative length of the record would show that two instead of one had

been transmitted. The advantages of dispensing with the dash are: first, less time is required to send the dot; and, second, the line does not accumulate so great a static charge by the brief connection to the battery in producing a dot as in producing a dash, while the impulse is sufficient for the signal. All spaced letters and long dashes, peculiar to the Morse alphabet, are excluded, the Continental alphabet being used.

The perforating apparatus for preparing the message for transmission consists of three telegraphic keys, representing a dash, a dot and a space, with steel punches operated by electro-magnets responding to the dot and dash keys, and a clockwork which moves the ribbon one step after the action of each punch, the space key being used after each letter and twice after each word. Such an apparatus is cheaply constructed, as compared with perforators which have a key for each letter of the alphabet. It can be operated at the rate of about twenty-five words per minute, which is about the speed of commercial telegraphy.

The transmitter is an apparatus consisting of a reel, upon which the perforated ribbon is wound, drums between which the ribbon is drawn, revolved by an electric motor, which is run at any desired speed, and contact brushes, or fingers, pressing upon either side of the ribbon, and meeting through the perforations to close the circuit; one pair on one line of perforations forming the dashes, and another pair forming the dots. This system of contact brushes ensures a perfect closing of the line, as the brushes are made of wire fibres, which are kept bright by the rubbing contact with the ribbon, and, when meeting through the perforations, interlace with each other. In all other automatic systems this contact has been made by a wheel, or brush, with the drum, and has resulted in much uncertainty.

The receiver of the system is an apparatus which consists of a reel with chemically prepared paper, moistened, wound upon it, pulleys or drums operated by an electric motor which can be run at any desired speed, and a recording stylus pressing upon the paper; also a device by which a local magnet stops the revolution of the reel as soon as

the message is finished. The stylus in this system has three points, one of which responds to positive currents and records the dots of the alphabet, and the other two, which are arranged on either side of the first, record in duplicate the dashes of the alphabet, and respond to negative currents. It will thus be seen that the battery current is reversed as often as a change is made from dashes to dots, and *vice versa*.

The committee charged with this investigation saw the apparatus in operation at the Franklin Institute, and afterward at the Philadelphia Bourse. Prior to that, one member of the committee saw it in operation over a commercial line 218 miles long, under the most unfavorable atmospheric conditions, the rain falling in torrents the entire length of the line. The conditions at the Institute and the Bourse simulated those of a commercial line in resistance and static capacity as nearly as that could be done by rheostats and condensers. In every instance the record received was clear and perfectly legible, the speed ranging from 940 words per minute over the commercial line to 2,000 words per minute over the artificial line.*

The investigating committee is of the opinion that the device of sending impulses of equal length into the line, whether representing dots or dashes; the receiving of these impulses in different lines on the recording strip, by the use of a suitable stylus and by the reversal of the polarity of the current; the invention of a contact brush, which ensures a perfect contact at any desired speed, and the many small details in the apparatus not specifically mentioned in this report, which, combined, produce a certainty in the results not hitherto attained in the art of telegraphy, and secure a speed in transmission and reception many times greater than by any other method, all constitute an invention of the first class, and are worthy of the highest commendation.

The Franklin Institute, therefore, awards the Elliott Cresson Medal to Patrick B. Delany for his system of machine telegraphy.

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* An illustrated description of the apparatus will be found in the *Journal of the Franklin Institute*, January, 1896.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 5, 1896.

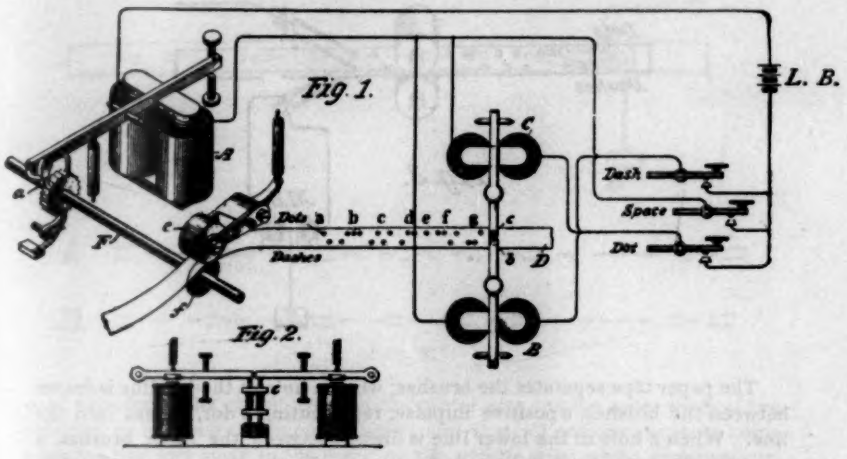
JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

G. MORGAN ELDRIDGE,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The following illustrated description will serve to give a clear impression of the details of the apparatus and mode of operation :

The Perforator, Fig. 1, comprises three keys—dot, dash and space key; two electro-magnets for forcing the punches through the tape; and a step-by-step tape-feeding device, also controlled by an electro-magnet.



The operation is as follows: The ribbon is perforated in two lines, the holes in the top line representing dots, those in the lower line dashes. The letters are made of combinations of dots and dashes, preferably according to the Continental Code. The lower contacts of the three keys are connected to one pole of the battery, *L. B.* The dot-key lever is connected to the punch magnet, *C;* the dash lever to punch magnet, *B;* and the space lever to space magnet, *A*. Obviously, but one key is pressed down at a time. The spacing magnet is in series with the dot and the dash magnets. To punch the letter *A*, the dot key is pressed down, magnet *C* forces its punch through the paper, and, at the same time, the lever of the space magnet is drawn down, and pawl *a* takes a new tooth in the ratchet wheel on shaft *F*. When the key is released and the circuit broken, the punch is raised out of the die and the strip is drawn a definite length by the sawtooth wheel *f*, and pressure wheel

e. Then the dash key is operated in the same way, after which the space key is touched, which provides a space between the letter punched and the one which is to follow. Thus, the space key is pressed down once after each letter, and three times after each word.

Perforating is no more laborious than working an ordinary Morse key, and the speed, with a little practice, will be fully up to the average of Morse transmission.

A side view of the punch magnets, their levers and punches, is shown in *Fig. 2*.

The Transmitter, Fig. 3, consists of a paper-pulling device, represented by roller, *R*, and the two pairs of wire brushes pressing toward each other above and below the tape. The top brushes are electrically one, and are connected to the line, *L*. The bottom brushes are insulated from each other, one being connected to the positive, the other to the negative pole of the main transmitting battery, *M B*. This battery is connected to earth at its middle.

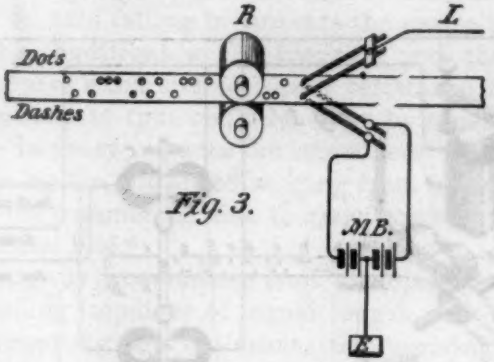


Fig. 3.

The paper tape separates the brushes; when a hole in the top line is drawn between the brushes, a positive impulse, representing a dot, is sent into the line. When a hole in the lower line is drawn between the other brushes, a negative current, representing a dash, is sent. In this manner all the dots and dashes on the tape are transmitted.

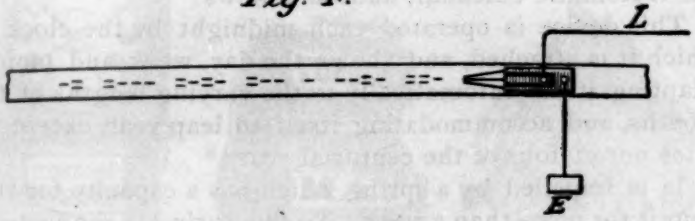
The brushes are made up of six wires each, so that six contacting points come together at each perforation. The ends of the brushes are kept bright and clean by the edges of the holes, and a pressure may be put on them which will insure electrical contact with the tape moving 30 feet per second, or at the rate of 8,000 words per minute, or over 2,500 impulses per second. An electric motor is used to pull the perforated tape.

As no dashes are sent, but only dots, which, owing to their position on the tape, *represent* dashes, the impulses are of uniform duration, and the line is not more heavily charged at one time than another; and consequently, the discharge is also uniform, and the signals on the receiving tape are correspondingly regular.

The Chemical Receiver.—The receiver is shown in *Fig. 4*. It comprises a wheel over which the chemically moistened tape is drawn under three thin iron wires which press lightly on top. The two outside wires are electrically one, and are connected to earth. The middle wire is insulated from the others, and is connected to line.

When the brushes of the transmitter drop into a hole in the dot line, a positive current is sent, and a dot is marked in the track of the middle wire of the receiver. When the transmitter brushes drop into a hole in the lower or dash line of perforations, a negative current is sent, and a dot is marked in duplicate on the receiving tape, one in the track of each of the outside wires. This impulse is but a dot in duration; but as it is meant to represent a dash, it must have something to distinguish it from the dot signal; therefore, the current is forked or divided on the receiving tape, so that all dashes are in the form of double dots, while the dots proper are single, and occupy the centre line on the tape. It will be understood that the chemically moist-

Fig. 4.



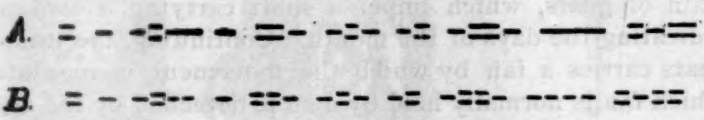


FIG. 5.

ened tape forms the circuit between the center wire and the outer wires of the receiver, or between the line and earth; and that all positive currents come over the line and mark in the track of the middle wire, while negative currents come from the earth, and mark in the track of the forked contact, forming double dots, which are recognized as dashes.

In this way, no matter how bad the "tailing" may be, it is impossible to mistake a dot for a dash, or to connect them together erroneously; neither is it necessary to have definition between successive dots or dashes. The length of the composite, single or double mark, determines at once the number of distinctive marks intended.

The specimens of record, *A* and *B*, seen in *Fig. 5*, illustrate this most important feature. *B* shows the word "telegraphy" with clearly defined individuality of each dot and dash. *A* shows the same word without any definition whatever, but, notwithstanding, the word to a practiced eye is just as plain in this form as the other.

THE PRENTISS AUTOMATIC CALENDAR.

[*Being the Report of the Committee on Science and the Arts on the invention of Henry S. Prentiss.*]

[No. 1888.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 29, 1895.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the Prentiss Automatic Calendar, finds as follows:

This device is operated each midnight by the clock to which it is attached, and shows the day, week and month, adapting itself automatically to the varying lengths of the months, and accommodating itself to leap year, except for three out of four of the centurial years.*

It is impelled by a spring which has a capacity for running it for more than a year. To this spring is connected a train of gears, which impel a shaft carrying a card-rack indicating the days of the month. Continuing, the train of gears carries a fan by which the movement is regulated, which fan is normally held by a stop, detached by the clock at midnight.

The card-rack consists of sixteen wire loops, loosely connected to two discs on the shaft, each carrying on its points a card, which cards are numbered serially on one side from 1 to 16, and on the other side from 17 to 31, with the card between 30 and 31 blank. These cards revolve with the shaft, and are successively brought to a perpendicular position by a stop on the front of the machine. Parting from this stop, the card drops upon the card which preceded it,

* The subject of this report is covered by U. S. Letters-Patent Nos. 360,725, 417,742, 428,318, 428,319, 441,443, 458,490; dated, respectively, April 5, 1887; December 24, 1889; May 20, 1890; May 20, 1890; November 25, 1890; August 25, 1891.

the bottom of which is inclined forward by the other cards on the rack, with the result that the direction of the card is changed and the edge which was in advance, and nearest the shaft, now becomes the following edge, farthest from the shaft; and, at the next presentation of the card at the stop, the opposite face is exhibited, giving all the days of the month on the sixteen cards with great compactness and simplicity; showing a card of 2¼ inches in depth, bearing a

FIG. 1.

FIG. 2.

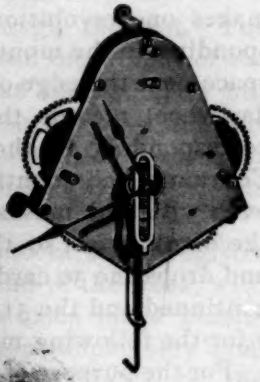


FIG. 3.

figure 2 inches in length, within a thickness of 4¼ inches. Geared to the shaft carrying the card-rack is the day-wheel, which makes one revolution each month, and is divided on its periphery into thirty-two spaces, thirty-one of which are armed with teeth which successively engage with a lever, which, when actuated by the tooth, rotates a cylinder carrying the days of the month, the forward movement of the card-rack shaft during this operation dropping a day card and substituting another The blank space on the day-

wheel corresponds in position to the blank card on the rack, allowing the shaft to rotate two day spaces, dropping the blank card as well as that showing 30, and leaving 31 exposed. On this shaft is also a cam, which engages with a lever connected to the cylinder showing the months. During the rotation of the shaft this lever is gradually drawn down by the cam until, on the first day of the month, the lever is released and, impelled by a spring, rotates by one point the cylinder showing the month.

On the face of the day wheel, near the blank tooth space, is a month wheel, divided on its periphery into twelve spaces, one for each month. At each revolution of the day-wheel the month-wheel engages with a projection of the frame, and is rotated one month space, and, accordingly, makes one revolution in a year. In the positions corresponding to the months having thirty-one days, its month-space next the edge of the day-wheel is inoperative, and the day-wheel records the thirty-one days. In the positions corresponding to the months having thirty days and to February, the month-space on the month-wheel projects even with and masks the tooth on the day-wheel next after the blank space, so that when the shaft is set in motion, and drops the 30 card and the blank card, the movement is continued and the 31 card is also dropped, showing next the 1 for the following month and changing the month.

For the purpose of regulating the apparatus for February and for leap year, there is, on the face of the month-wheel, a February wheel, having four projections, one of which, at each rotation of the month-wheel, engages with a projection on the face of the day-wheel and moves the February wheel one-fourth of a turn, this wheel making one revolution in four years. On the face of the day-wheel are two cams, corresponding in position to, and, when raised, making the teeth for the day-cards 29 and 30, so that, when these cams are in operation, the day-wheel moves continuously from 28 to 1. In three of the four positions of the year-wheel, when the February twelfth-space of the month-wheel is in action, both of these cams are raised by a pin on the year-wheel and are operative; but in the fourth position of this

wheel, the pin engages only that one of these cams which masks the 30 tooth, and the 29 card is consequently exhibited in its turn, the day-wheel passing thence to the 1.

The device is started in operation by tripping a lever at its top. To effect this automatically, without complicated mechanism in the clock, a wheel having a volute cam of two turns is placed on the shaft carrying the hour hand, and a looped rod passing over this shaft engages with this cam. Passing the end of this cam, which it is timed to do at midnight, the looped rod drops through a slot made for that purpose and strikes the lever. The slot extends through both turns of the volute cam; but the rod passes over it on a bridge of a loose piece, which then falls out of the way to allow the rod to drop through the slot. The spring on the lever is sufficient to sustain the weight of the rod, but yields under the blow, so that the action is but momentary. The applicant shows a device by which this operation is performed electrically, so that the calendar can be operated by the clock elsewhere than within its case.

Calendars adapted to be operated by clocks, and to register the month and the day of the month and of the week, with accommodation for the leap year, have been made heretofore; but the present one is exceedingly simple, very compact, positive in action, and readily adaptable to the movement of any clock. The whole apparatus occupies a space of but 9 inches wide, 14 inches high and 4½ inches deep, showing the month and the day of the week in letters ⅛ inch long, and the day of the month in figures 2 inches long. The arrangement of cards—by which sixteen cards, of 2¼ inches in height, show all the days of the month in figures 2 inches long, occupying a space in the clock-case of less than 4½ inches in depth and 5 inches in height—is specially commendable.

For the ingenuity displayed in condensing the mechanism accomplishing these results, the Franklin Institute recommends the award of the John Scott Legacy Premium and Medal to Henry S. Prentiss, of New York City, N. Y., for his Automatic Calendar.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 11, 1895.

JOS. M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

SAMUEL SARTAIN,
Chairman, Committee on Science and the Arts.

Award confirmed by the Board of Directors of City Trusts.

APPENDIX.

Fig. 1 shows the complete calendar clock, *Fig. 2* the calendar movement and *Fig. 3* the clock movement. By reference to *Fig. 1* it will be seen that the day-of-the-week, month-of-the-year and day-of-the-month are all shown in full-sized letters and figures, which appear directly behind the sight-openings or windows in the case. They are sufficiently close to the glass of the windows to give a clear and desirable effect, the white margin of the mats adding considerably to the general result, and making the names and dates stand out in such a manner as to appear much larger than they really are.

Fig. 2 shows the calendar movement, and also the drop-rod and release-lever by which the calendar is started. The "21" is shown at the sight-opening, and on the starting up of the mechanism this card first drops down out of the way and lies close to the number "20," while a further revolution of the card device allows the "22" to drop into the position formerly occupied by the "21." The regulator-wheel and month-wheel may also be seen on the left of the cut.

Fig. 3 shows the clock movement, and also the cam and drop-rod which set off the calendar. The drop-rod falls sufficiently to strike the release-lever a sharp blow, and then rebounds and is held up and out of the way by its spring.

FOREST FIRES IN NEW JERSEY.

BY JOHN GIFFORD,
Forestry Agent for the Geological Survey of New Jersey.

The question of fires in New Jersey demands immediate attention. It is the main cause of forest deterioration and its consequences, and of the impoverished condition of a large part of the State of New Jersey. There are very few stretches of woodland in this region which have not been thus affected.

The causes of forest fires may be classified as follows:

(1) Incendiarism.
(2) Carelessness.
(3) Sparks and hot coals from locomotives.
(4) Lightning.

The most serious fires are usually those which are purposely set, because set at the proper time and in the proper place. An incendiary bent upon mischief waits until the wood is dry and the wind in the desired direction. There are usually two motives back of incendiarism:

(1) Individual gain at the expense of another.
(2) Revenge.

A few years ago it was not uncommon for colliers to fire a wood in order to buy it cheaply. The charred wood is then only fit for charcoal. Owing to the decline of the charcoal industry and the abundance of charred wood in the forest, this is no longer profitable. Fires were set in meadowy regions to improve the grass for cattle. Savanna lands are still burnt for that purpose in regions where cattle are turned into the woods. Berry-pickers set fire to huckleberry bushes to improve the berry crop. In a couple of years, the young growth which follows bears larger and finer berries. Wood thieves, it is said, set fire to the brush and stumps to hide their tracks. There are many people living in the backwoods of New Jersey who own no woodland, but who gain a livelihood in a variety of ways out of woods which belong to other people. They are mostly berry-pickers, hunters and wood-choppers.

Fires are set out of spite. If a backwoodsman thinks himself wronged by a woodland owner, he "gets even" by touching a match to his woods. It is certain that for several purposes forest fires are set. Such fires do much damage, and the conviction of such incendiaries is difficult.

Woodland owners, during forest-fire season, feel insecure, expecting a fire at any moment. The incendiary may set a fire to injure an enemy, but the wind may suddenly change and many others may suffer in consequence. Several fires in Atlantic County were set last season in the same region several nights in succession.

Second in importance are fires caused by careless individuals. In clearing land, fires escape from burning brush. A large foreign element has come to South Jersey to clear farms. This increases the danger from fires while the land is being cleared. Tramps, hunters and boys, with camp-fires, lighted cigars and cigarettes, cause many fires.

Locomotives also are often blamed. It is certain that many fires have been set by sparks from the stack and hot coals from the grate. The greater number of the railroads are using some care. On some roads, engineers are cautioned, safety strips are cleared, and, in one instance, furrows have been ploughed along the road, and section-men usually endeavor to put out the fires which are thus caused. If engineers are careful, if the spark-arrester is not withdrawn or poked with holes, if coals are dumped in places prepared for that purpose, and if safety strips are cleared and furrows ploughed along the road, and section-men are watchful and willing, there is little danger from that source. It is certain that some railroads are using more precautions at present than woodland owners themselves.

Although not common, fires have been set by lightning. Certain species and solitary trees are more apt to be struck than others. There are several indications that a disastrous fire was set last summer in South Jersey, by lightning, which struck a solitary tree in a field of dry grass.

The effects of fire may be classified as follows:

(1) Destruction of timber and other property.

(2) Extinction of valuable species.

(3) Impoverishment of soil.

(4) Destruction of seeds and game.

(5) Consequential damage, by affecting industries dependent upon the woods, and by changing moisture, soil and climatic conditions, which are more or less dependent upon a forest cover.

The amount of damage depends, of course, upon the severity of the fire, which, in turn, depends upon the dryness of the wood, the force of the wind and the nature of the trees and underbrush.

Often everything above ground is killed. The charred

boles of hundreds of trees fall and rot in the woods. In low ground, after a fire, fresh green underbrush soon appears. High land recovers slowly, often remaining bare for many years. There is danger from fires about six months of the year. They are very destructive during the high winds in the spring, when there is little sap in the wood.

Dry leaves cover the ground, and many cling to the low oaks.

Certain trees are affected much more than others. This depends mainly upon the nature of the bark. Often, large pine trees appear to be but slightly affected by a ground fire, which burns the underbrush and leaves on the surface. Bark is a non-conductor of heat; but if the cambium, the active part of the tree just beneath the bark, is affected, the tree dies.

Even then, if it happens in spring, the tree appears to be recovering. Dormant buds in the trunk sprout, and fresh, green leaves are formed.

It is better to cut such trees at once, because they soon die. When the starchy matter in the trunk is exhausted, these sprouts wither and die, the tree is invaded by insects, rots and topples over. Even a pine log, if cut in the winter, sends out fresh shoots in the spring from dormant eyes. Even if the tree is not itself directly injured, its supply of nutriment and moisture is affected by burning the undergrowth.

The value of underbrush must not be underrated. Although it smothers young trees, it is useful to forests of larger growth. The amount of mineral matter which a tree absorbs is insignificant. Water is the essential element. In checking evaporation and retarding the flow, undergrowth is often necessary. But the smaller amount of dead wood in a forest the better, since it breeds many kinds of insects, some of which may invade the living trees. The material resulting from decay, however, enriches the soil, so that it is better to burn the dead wood which cannot be utilized. In that way the soil is enriched just the same, the insects are disposed of, and the underbrush is not seriously

disturbed. It is easy to see, therefore, how fire in a forest is often useful if wholly under control and directed by a forester.

In old pine woods, on upland, there is often little underbrush. The ground is covered with a thin layer of pine leaves.

Stump holes are common in such woods. When a pine tree is cut or burnt the stump decays and a hole of considerable size, with many ramifications, is formed. The ground is often riddled with holes from suppressed trees. These drain the water from the surface.

This, together with the slight shade of pines and lack of underbrush, accounts for the dryness of the soil and atmosphere in a pine woods. Many trees are soon affected by removing underbrush. The growth of a young oak grove can easily be retarded by trimming the lower limbs and removing the undergrowth.

Since one species is affected more than others, a kind of selection continues, which accounts for the peculiar distribution of trees in certain places. Thick-bark trees, and trees which produce a vigorous coppice growth, survive the longest. Pitch pines and oaks, therefore, predominate in South Jersey, while in isolated positions, protected from fires, a great variety of trees may be found. Certain plants, although covered with a thick bark, contain substances in the form of resin, oils and waxes, which are inflammable. Others contain substances which have a tendency to quench fire. The sowing of such plants along safety lines has been suggested to prevent the slow but destructive ground fires. The white cedar (*chamæcyparis thyoides*), the most valuable timber tree in South Jersey, and one of the most valuable in America, although growing in wet swamps, is often seriously damaged by fire.

The heat, although it may not burn, is often sufficient to kill the cedar. In unusually dry weather fires burn for many days in the bed of a swamp. It is often necessary to dig deep trenches in order to check its headway.

It destroys cranberry bogs in a similar fashion. For fear of fires, cedar is cut when fit only for rails, hop-poles and laths.

The soil is much impoverished by fire; this is the testimony of a large majority of farmers. The "life" is "cooked" out of it, as they say. The organic matter in the surface soil is often entirely burnt. The surface is bared so that the soil is soon completely leached.

Prof. F. H. Storer, in *Agriculture*, says: "Within porous soils nitrates are doubtless formed rather freely, and, as is well known, the nitrates are easily washed out from soils, and are liable to go to waste after every rain that is long continued. They are, in fact, leached out of the soil, and the manure from which they came rapidly wastes away. It is said to be a matter of old and familiar observation in Germany, that in sandy regions, in seasons that are particularly wet, the soil may finally be so thoroughly leached that it becomes unfruitful. When we consider the facts that nitrates are easily washed out of the soil, that they are absolutely essential to plant growth, and that they are continually produced, during the period of growth, from humus, by the action of nitrifying bacteria, we can appreciate the damage to light soils by fire. Land thus damaged needs very careful tillage and green manuring before it can produce a crop of consequence."

When a pine woods twenty years old is destroyed it may mean many years before the soil recuperates and seeds are again disseminated. Seeds on the surface are destroyed by fire. Some seeds are seriously affected by slight changes of temperature.

Also, many animals are destroyed. In the spring of the year the young are burnt in the nest. It is not uncommon to see many of the smaller animals chased before a fire. By preserving the forest, the animals dependent upon its fruits are preserved.

According to the statements of several seamen, the smoke and fog which the forest fires produce were a serious impediment to navigation along our coast last summer.

The total area burned over in South Jersey during the past season of 1895 amounts to not less than 197,000 acres. No improvement in the forest conditions of a country is possible as long as fires are allowed to burn without any

systematic preventive measures. With no protection whatever against incendiaries and individuals guilty of malicious carelessness, the owners of woodland are at the mercy of chance. In consequence, wood is usually cut just as soon as there is a market of any kind. Property in some towns in South Jersey is often endangered. Under such conditions capitalists hesitate to invest in woodland.

If a fire breaks out, it is seldom noticed until it has attained considerable size. The owner of the land coaxes and lures a few men to help him fight it. A fire often burns for some time, owing to the fact that competent men cannot be found. Many refuse to fight in the daytime. They wait until evening, when the fire is smouldering. Many fighters do more harm than good. These men are generally not paid. Often they are allowed to cut the dead wood. When this is refused, the land-owner is considered mean, and often has difficulty afterward in finding fighters. When allowed to cut dead wood, the privilege is usually abused. When a fire once gains headway in a dry woods, propelled by a strong wind, it is difficult if not impossible to check. Such work requires brave, skilful men, familiar with the region, and not chance men picked up here and there. The rapidity of spread of the fire depends, of course, upon the condition of the woods and the strength of the wind.

Although these fires are rapid, and although the sparks may fly long distances, a stream, spur of swamp, or even a road, are often sufficient to check their headway. Many fires which are very destructive burn for some time without being noticed.

The method of fighting is by back-firing. After the wind and other conditions have been noted, a party goes ahead to a road, which is always an excellent point of vantage, and burns back toward the fire. If possible, furrows are ploughed. The fires meet, and the force of the main body of fire is checked or diverted. Back-firing on another man's property to save your own, often causes trouble.

This much is certain about fires in South Jersey, that back-firing, in the proper way, is the most practical method of checking a fire, and that roads are excellent points of van-

tage. The clearing of roads for some distance on each side, and the burning of safety strips at the proper season, are important steps toward the prevention of fires. Were large tracts of woodland divided into sections, and each section surrounded by fire lines, there would be less danger. South Jersey is such a mass of woods, that when fire once gains headway, it travels for miles without meeting with opposition. Fires can be much more easily controlled in South Jersey than in a mountainous region. Sand, which is excellent material to fight with, is, fortunately, plentiful.

Proper policing by a mounted, organized, well-directed force of wardens, is necessary. The territory must be divided into districts of a certain size, irrespective of political divisions, with a warden to each district, with the woods, roads and clearings of which he must become perfectly familiar. He must be held responsible for that district. Stationed on an eminence, with field-glasses, one man can control a large area in South Jersey. It must be his duty to enforce regulations and to apprehend and bring to court all offenders. It must be his duty to keep a strict record of fires and other facts concerning the forests of his district. With a corps of twenty-five brave, skilful men, organized and under one head, fires can be reduced to a minimum, if not altogether stopped in the southern interior of New Jersey. These wardens must have the power to call on men to help them when necessary. These men must be under his control, and be paid fair wages for their work. Fighting fire is such a disagreeable and laborious task that there is little wonder competent men who will work for nothing are difficult to find. Experience in other countries shows that the presence of wardens has a strong educational influence. Twenty-five good men, for six months of the year, could be procured for $500 each. Allowing as much more for other expenses, $25,000 would cover the cost of such a force.

Considering the damage during the past season, there is economy in such a measure.

The prevention of fires is a difficult matter. It can be accomplished only by the co-operation of railroads, a large majority of the woodland owners and public-spirited citi-

zens, coupled with the aid of the proper kind of laws, backed with ample means for their enforcement.

To sum it all up, fires can be reduced to a minimum by removing the causes. Many of these causes are avoidable and will not exist if there is the proper kind of laws, with ample machinery for their enforcement. The few fires which are unavoidable can be extinguished in their incipiency if there is a warden present, who knows just what to do and how to do it.

THE CONDITIONS WHICH CAUSE WROUGHT IRON TO BE FIBROUS AND STEEL LOW IN CARBON TO BE CRYSTALLINE.*

BY W. F. DURFEE, C.E.

MR. CHAIRMAN AND GENTLEMEN:

I am announced to speak to you this evening upon the conditions which cause wrought iron to be fibrous and steel low in carbon to be crystalline.

In discussing this subject, the views which I shall present for your consideration are a few of the observations and conclusions derived from a somewhat intimate practical acquaintance, during the past forty years, with the manufacture and employment of both iron and steel; and I offer them as contributive to a correct understanding of the structural relations of these metals, or as indicative of their proper treatment in the course of manufacture and use.

The opinion is common among users of wrought iron and soft steel that the former has no carbon associated with it; and the belief is also prevalent that the minute percentage of carbon (0·10 to 0·15 of 1 per cent.) in the latter is at once the cause and explanation of the structural dissimilarity of these metals.

*A lecture delivered before the Franklin Institute, January 31, 1896. Some of the matter of this lecture was presented in a lecture delivered by the author before the United States Naval Institute, at Annapolis, in 1887, and will be found published in the *Proceedings* of that Institute for that year.

Like many other popular opinions and beliefs, these are not established upon those hard, unyielding, azoic rocks of knowledge — well-ascertained facts — on which all true science is founded; for it is well known to investigators that the best fibrous wrought iron contains as much or more carbon than the average crystalline soft steel. As illustrating this fact, the following table* will be found of convincing interest.

PERCENTAGES OF CARBON IN SOME VARIETIES OF IRON AND STEEL.

SERIES OF THE IRONS.

Description.	*Percentage of Carbon.*
Soft puddled iron	trace*
Armor plates	0·016†
	0·033†
	0·044†
Iron rail	0·09‡
Lowmoor boiler-plate	0·10‡
Staffordshire boiler-plate	0·19‡
Russian bar iron	0·272†
	0·340†
Swedish bar iron	0·054†
	0·087†
	0·386†
Steely puddled iron	0·30 to 0·40‡
Iron made by Catalan process direct from the ore	traces†
	0·420†
Soft puddled steel	0·301†
Puddled steel rail	0·55‡
Hard puddled steel	1·380†

SERIES OF THE STEELS.

Description.	*Percentage of Carbon.*
Extra soft Fagersta Bessemer steel	0·085‖
Extra soft Dowlais Bessemer steel	0·135‖
Crewe boiler-plate steel, Bessemer process	0·22 to 0·24¶
Locomotive crank-axle Seraing Bessemer steel	0·31‡
	0·49‡
Locomotive crank-axle, by Vickers, Sheffield	0·46*
Rails and tires	0·30 to 0·50
Bessemer spring steel	0·45 to 0·55‡
Crucible Steel.	
For masons' tools	0·6*
For chipping chisels	0·75
Crank-axle (by Krupp)	1·05‡
Gun (by Krupp)	1·18†
For flat files	1·20*
Forged Indian wootz	1·645†

* A. Willis. † J. Percy. ‡ A. Greiner.
‖ D. Forbes. ‖ Snelus. ¶ F. W. Webb.

From this table it is evident that Lowmoor iron boiler-plate has more carbon than extra soft Fagersta Bessemer steel; that Staffordshire boiler-plate has over twice as much carbon as Fagersta steel; that some samples of Russian and Swedish bar iron have over four times as much carbon as the Fagersta steel; and, finally, that a sample of wrought iron made by the "Catalan" process (which produces exceptionally good wrought metal) had five times as much carbon as the Fagersta steel.

There can be no mistake in the foregoing figures, for they

* From a paper read before the Institution of Civil Engineers, London, in April, 1875.

are the work of men world-famed for their intimate knowledge of the metallurgy of iron and steel, and unimpeachable as regards their conscientious skill as chemists.

Having thus shown you that the absence of carbon cannot explain the presence of fiber in wrought iron, it remains for me to lay before you the reasons for the peculiar structure of that metal.

Allow me, first, to endeavor to answer the question: "What is wrought iron?"

The following circumstances make the correct apprehension of this question difficult, viz.: (1) the way in which a mass of wrought iron is built up is not generally understood; and (2) the difference of its structure from that of a homogeneous material is not fully comprehended.

The term wrought iron is popularly supposed to designate a metal; but it is really the name of a mechanical admixture, which, at its best, consists of clusters of crystals (which may with propriety be regarded as compound crystals) of practically pure iron, separated from one another, as the result of the manipulative processes employed, by films or threads of an unavoidable impurity, called "cinder." By crystals of iron, I mean minute ultimate structural units of that metal, bounded by well-defined planes, whose intersections always form salient angles. A number of such crystals may cohere and form an aggregation, having bounding planes similar in outline and relative arrangement to those of any single crystal. Such aggregations or compound crystals vary in size and are often regarded as single crystals and spoken of as such, just as we speak of crystals of galena, or calcspar, when, as a matter of fact, the ultimate crystal of each of these substances remains undiscovered, and as undiscoverable as the boundaries of space. These large or compound crystals of wrought iron are, in themselves, practically homogeneous; that is to say, the ultimate crystals of which they are composed are not separated and kept apart by any foreign substance, but are as nearly in actual contact as the law of cohesion, in obedience to which they were formed, will admit. In the manufacture of wrought iron, the "pig," or other variety of cast iron, is first deprived, in a

more or less imperfect degree, of its carbon and other impurities, by what is known as the "puddling process." This process may briefly be described as consisting of four distinct operations, viz.:

(1) The melting of the "pig iron."

(2) The "boiling" of the melted metal in a bath of liquid "cinder" (composed mainly of silicate of protoxide of iron), until the iron (which, owing to its loss of carbon and other impurities, can no longer remain fluid at the temperature employed) begins to solidify in the form of small granules or crystals, which can be seen moving amid the boiling "cinder" like white-hot peas in a red-hot soup.

When the iron begins thus to granulate or crystallize, it is said to be "coming to nature."

(3) The collection, by the puddler, of these granules or crystals into distinct masses, called "balls," which may with propriety be regarded as white-hot sponges of iron saturated with liquid "cinder," which fills all their numerous accidental and irregular cavities.

(4) The "squeezing" or "hammering" of these "balls," while still at a welding heat, into more solid masses, which are called "blooms." These contain much less "cinder" and other impurities than the "balls," but are far from being uniform in structure; for, when the "balls" are "squeezed" or "hammered" (this last operation is often called "shingling") for the purpose of expelling the "cinder" and welding the granules or crystals of iron into a homogeneous mass, the attempt is never wholly successful; also, as the metal cools, the "cinder" quickly acquires a pasty consistency and flows with difficulty, and a large portion enclosed in the interior cavities of the "ball" is merely flattened or elongated. Hence, it will be seen that the "bloom" is composed of a compacted mass of granules or crystals of iron, separated from one another at numerous points by films, layers, or strings of "cinder" of very irregular dimensions, but which, notwithstanding, are mutually attracted with a greater or less degree of force, the minimum value of which is a measure of the cohesive strength of the mass.

Now, let us follow the "bloom" as it progresses towards the form of a commercial bar of wrought iron, and examine carefully the structural changes which take place during such progress.

When a properly-heated "bloom," or other similarly constituted mass of wrought iron, is subjected to the action of the hammer or rolls, the contained "cinder" endeavors to escape from its entangled mechanical alliance with the crystals of the iron, and in so doing, each particle thereof is driven into some line of least resistance, which is always finally located in a plane at right angles to the direction of the force acting upon the metal. In other words, if the bloom is rolled or forged into a rod or bar, the metal will be acted upon in two directions at right angles to each other,* and its compound crystals will be compressed in directions normal to the exterior surfaces of the bar, and at the same time extended in the direction of its length.

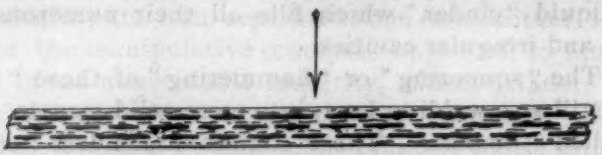


FIG. 1.

Thus the ends of adjacent crystals are forced towards each other, and the intervening "cinder" is compelled to move at right angles to the axis of the bar and to unite with the films or threads of "cinder" which have become established in parallel lines of least resistance along the flanks of the compound crystals, and at right angles to the direction of the force acting upon the bar.

Fig. 1 is intended to illustrate, on an exaggerated scale, this arrangement of the elongated compound crystals of iron with intervening films or threads of "cinder," the light spaces representing the iron crystals and the dark lines the

* In forging a bar it is the usual practice to turn it about its axis through an angle of 90° between the blows (or series of blows) of the hammer; and in rolling a bar it is commonly turned through the same angle between "passes" through the rolls.

"cinder"—the force of compression being supposed to act upon the bar in the direction of the arrow.

The direct consequence of the elongation of its compound crystals, and the effort of the intervening "cinder" to escape in the direction of least resistance while the wrought iron "bloom" is being forged or rolled, as before described, is the establishment of that structural peculiarity in the resulting bar, known as "fiber," which is one of the most conspicuous features of wrought iron, and one not found in any other variety of ferruginous materials.

When certain of the films or threads of "cinder" in a bar of "wrought iron" are so large as to be distinctly visible on its surface to the unassisted eye, they are called "sand seams" or "cinder cracks."

If its compound crystals are nearly pure iron, the bar can readily be bent cold without fracture, and if pulled asunder by a gradually augmented force, its fibrous texture is at once evident; but in case the compound crystals have chemically combined with some substance, such as phosphorus or silicon, which tends to diminish both the cohesive attraction between the ultimate crystals of which they are composed and the mutual attraction of the compound crystals, then the bar cannot easily be bent cold without rupture, and is said to have a crystalline fracture.

Notwithstanding this apparent absence of fiber, the mechanical structure of the bar is the same as before; that is to say, the "cinder" and elongated compound crystals are still arranged in lines parallel with the axis of the bar, and occasionally connected by branches at right angles thereto.

Whenever a "bloom" is subjected to a force of compression always acting perpendicular to the same plane, as is the case when it is rolled into a "sheet" or "plate," its compound crystals and accompanying cinder are each flattened and extended parallel with that plane, and the resulting "sheet" or "plate" has more of a laminated than of a fibrous structure, being built up of a number of leaves or strata of iron separated from each other by films of "cinder," which, when unduly thick at any point, cause defects in the plate, which are called "blisters."

The foregoing discussion of the structural characteristics of wrought iron brings to mind an important practical question, relative to the employment of wrought iron in construction, which has often been asked, viz.: Will a given sample of wrought iron, having a decidedly fibrous texture, become crystalline under the operation of a continued repetition of violent strains or shocks?

Doubtless many persons of large and varied experience in the use of iron will unhesitatingly answer this question in the affirmative.

The sailor who sees his chain cable (known to have been made of carefully selected, thoroughly worked and honestly tested fibrous iron) snap short, has no doubt about the metal having become crystalline, owing to lapse of time and rough usage.

The practical farmer, as he examines a broken trace or plow chain, is firmly of the opinion that the iron thereof had become crystalline by use.

The railway passenger who has fortunately escaped serious injury from an accident caused by a broken axle, is usually ready, even anxious, to testify, with emphatic confidence, that "the iron of the axle was crystalline and entirely unfit for the purpose for which it was used." Does a modern fiddle-string bridge go down under a passing train, plunging a whole community in mourning and sending a thrill of shivering horror through the land—among the various theories advanced to disguise the utter want of sufficient intelligently distributed material in the structure, is sure to be found that of the crystallization of the iron employed.

But let us return to our question. Can a bar of wrought iron of a pronounced fibrous structure be ruptured so as to exhibit a crystalline fracture? I answer, yes—in two ways:

(1) By a sudden application of a force of extension, commonly called a "jerk."

(2) By a prolonged repetition of a force of compression, sometimes called a "jar."

The first method of rupture may be said to consist of a transverse separation of the compound crystals of the bar,

as distinguished from a sliding of their interlocking flanks upon each other, as is the case when the rupture presents a fibrous appearance.

I have often seen crystalline fractures produced in truly fibrous iron. In the manufacture of iron rails (now practically an extinct industry) it was always considered desirable that they should be of a hard and crystalline texture as to their tops or "heads," but soft and fibrous in their bottoms or "flanges;" but however perfectly this distribution of metal was made, it was always possible to break a rail so as to show a crystalline fracture in its "flange." This was accomplished by making a slight "nick" across the "flange" (to determine the point of fracture), and placing the rail (flange down) in the "straightening press" on supports placed a short distance on either side of the "nick," and then putting in the "gag" *heavy* just over it—the result was almost always a crystalline fracture of the "flange"—in short, the elongated compound crystals were "jerked" asunder. But if the points supporting the rail were placed farther apart and the rail given an opportunity to yield considerably between them, then, if the "gag" was put in *light* a number of times in succession, the fracture of the "flange" would be sure to exhibit a fibrous texture, due to the fact that sufficient time had been given to break up the films of "cinder" between the flanks of the compound crystals and destroy their transverse cohesion, thus permitting them to slide apart and exhibit the appearance of disrupted fibers.

In *Fig. 2*, *A* represents a fracture of a bar of iron, such as would be made by a "jerk" or "jar." In this the compound crystals are separated transversely in or near the same plane, and from their appearance many would infer a total absence of fiber in the bar. In *B*, we see that the rupture was effected by an apparent longitudinal sliding of the strings or strands of compound crystals upon each other, in consequence of a prolonged "pull;" but such a movement of these strings or strands cannot possibly take place until every string or strand of crystals is first ruptured transversely; but this does not occur in or near the same plane,

as in the case of *A*, but each string or strand is transversely ruptured at a point some distance from the rupture of the neighboring string, or strands, and the final separation of the interlocking strands of crystals taking place by a sliding of the flanks of the aggregation of strings of crystals belonging to one part of the bar; along those belonging to the other part, very much in the same way as the longitudinally interlocked fingers of the two hands are separated by a sliding movement, on applying a tensile strain in the direction of their length for that purpose. The language seems to lack words to designate and distinguish these two methods and kinds of rupture; and if I may be permitted to coin a pair of words to fit the observed conditions, I will say

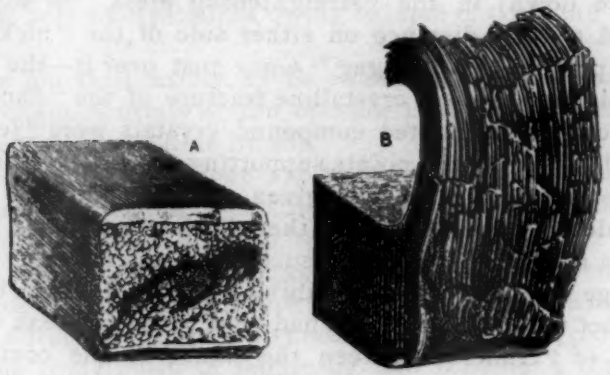


FIG. 2.

that the simple transverse crystalline fracture, *A*, is a homoplanic rupture, and the complex fibrous separation, *B*, is a heteroplanic rupture.

We are indebted to a not uncommon accident to which the hammer-bars of a peculiar type of steam-hammer are liable, for an excellent illustration of the second method of producing a crystalline fracture in fibrous wrought iron, the result of the repeated action of a percussive force of compression. In *Fig. 3* is represented, at *A*, the bar of such a steam-hammer. As before stated, there exists, in a bar of fibrous iron, films of cinder between the ends of its elongated compound crystals (as shown exaggerated in *Fig. 1*). These, from the nature of their formative process, cannot possibly

be of uniform thickness. This, considered in connection with the fact that the greatest force of the percussive action per unit of area of any cross section of the hammer-bar is exerted upon a section made by a plane cutting the bar at right angles immediately above its head, justifies the belief that at or near this point fracture will be most likely to occur. It is also evident that the percussive action of the hammer will have more destructive effect upon thick than upon thin films of "cinder;" while, at the same time, the force of cohesion between the ends of adjacent compound

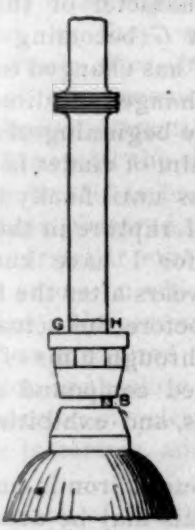


FIG. 3.

FIG. 4.

crystals will be diminished in some inverse proportion to the thickness of the films of "cinder" between them. It, therefore, seems exceedingly probable that the fracture due to continued percussion will take place, if not in the plane above-named, yet in one very near to it, in which the "cinder" films chance to be of greater thickness than those in that plane; and, as a matter of fact, fractures in such bars are usually within a few inches of the point where the bar enters its head, as at *G*, *H*, *Fig. 3*.

The particular point in the circumference of such a hammer bar where the imminent fracture first appears is

often determined by the manual peculiarity of the hammerman. A left-handed man will incline his work to the left, and a man who is right-handed will be likely to use the right side of the anvil more than the left. In this latter case, the work *B* (*Fig. 3*) will tend (whenever it is in the position shown) to produce a jarring tensile strain at the point *G*, and a jarring compressive strain at *H;* and if the work is placed on the center of the anvil, the strain upon the "cinder" in the plane *G*, *H*, will be uniformly distributed as a jarring compressive one, and as the work is shifted to the left side of the anvil, the character of the original strains becomes reversed, that at *G* becoming a jarring compressive strain, while that at *H* has changed to a jarring tensile strain. These irregular changes of direction and force of the jarring strain cause the beginning of a fracture at that side of the bar where the film of cinder is the thickest, and it gradually extends across until finally the bar is "jarred" asunder. The progress of rupture in the way just described is not usually rapid, for I have known of a hammer-bar being used over two years after the first manifestation of incipient separation before the actual rupture occurred, which then took place through films of "cinder" between the ends of the elongated compound crystals of the bar, thus exposing those ends, and exhibiting what is called a crystalline fracture.

It is a well-known fact that wrought iron is improved in strength by repeated working. This may be accounted for thus: In the initial heating and shaping of the metal, its crystals were left with a comparatively thick film of cinder between them; but, by each successive re-working, the crystals of metal are driven into closer order; some of the intervening "cinder" is expelled, and what remains is very much reduced in thickness, so that the cohesive attraction (whatever that may be) between these crystals, having less space through which to act, acts with augmented intensity.

It is well to remember that when we speak of "less space" in describing the contiguity of crystals of wrought iron, we are dealing with a very small dimension, in fact, one very near neighbor to the infinitesimal.

The mechanical action which takes place as the result of shock, in the films of "cinder" which separate the compound crystals in a bar of wrought iron, is believed to be somewhat as follows: Each individual "jerk" of extension or "jar" of compression slightly (this word must be taken as meaning in this connection, almost the minuteness of negative infinity) disarranges the molecules of the thickest film of "cinder" in the immediate vicinity of that section of the bar in which the shock is the most powerful, and, as the result of this disarrangement, the crystals of iron cannot be brought as close together under the operation of cohesive attraction, as they were before the disturbing shock, and as shock after-shock is experienced by the bar, its crystals of iron become further and further separated, and their cohesive attraction enfeebled, until finally it is not sufficient to resist the shock which ruptures the bar. This view may be said to be pure speculation; but if it accounts for the facts observed, it is quite as justifiable as the belief in the interstellar ether of astronomical physics, or of the ultimate atoms on which the modern science of chemistry is founded. No person ever saw, heard, smelt, tasted, felt, weighed or measured atom or ether; and yet, upon their recognition as absolute entities depends the explanation and comprehension of celestial and material phenomena, whose existence is certain, and whose importance cannot be overrated.

Very much of the difficulty of correctly comprehending the structure of the material of which we have been speaking may be eliminated by recognizing the fact that what is commonly called wrought iron is not, in its entirety, really iron; and remembering that the only way in which *pure iron* can be obtained is by electrolysis, a process, I need hardly say, commercially impossible for all practical purposes in the present state of our technical knowledge.

The belief in the so-called crystallization of fibrous wrought iron as the result of prolonged use is, I think, altogether a mistaken one, and I am clearly of the opinion that the crystallization observed in the case of any particular fracture existed just as we see it exposed in the break at

the time the metal was given the shape it had when ruptured. After a bar of distinctly fibrous wrought iron has been subjected to multitudes of sudden "jerks" of extension or "jars" of percussive compression, the "cinder" in some cross section of it (in which this impurity is slightly thicker than elsewhere) gets broken up, cohesion is destroyed, and the bar breaks with a crystalline fracture.

Time passes, and, though I could fill the fleeting hour with talk about iron, yet in this lecture, as in the field of mechanical construction, it is now fitting that iron should give place to steel.

What is steel? To the many answers to this frequently-asked question I will venture to add one more, viz.: steel is iron freed from mechanically-mixed impurities (such as "cinder," etc.), by a melting process, during which there is combined with it chemically a small percentage (not large enough to prevent the metal being forged or rolled) of other impurities, introduced for the purpose of modifying its strength, hardness, elasticity or ductility, in such way and degree as to adapt it to the particular use to which it is to be applied. In short, while wrought iron is iron having (as the unavoidable result of the methods employed in its manufacture) its impurities mechanically mixed therewith, steel is iron having (as the result of the adoption of appropriate manufacturing processes) its impurities chemically combined therewith.

Foremost among the substances chemically combined with iron to convert it into steel, is carbon. When this element exceeds 0·12 to 0·15 of 1 per cent., it begins to confer a hardening property upon the iron with which it is associated, but, at the same time, it does not destroy the forgability of the metal until its proportion attains about 1·5 per cent. Other substances have been added to iron in connection with carbon, for the production of special qualities of steel, and of these manganese, nickel, aluminum, chromium, tungsten and titanium are the most important.

I cannot, at this time, attempt to describe at length the various processes employed in the manufacture of steel, or

even its various properties and uses, but must confine my remarks, as intimated in my subject, to steel "low in carbon" —that is to say, to steel in which the carbon percentage is so low as not to confer a hardening property upon the metal; in fact, to steel in which carbon is present in as small proportion as in most wrought irons, or even smaller, and to certain practical details of its manufacture which I deem of especial interest and importance.

The most notable distinguishing difference between "low steel" and "wrought iron" is the want of "fiber" in the first-named material and its presence in the last. *Fig. 4* illustrates a method of showing by experiment the character of the structural difference between a bar of wrought iron and one of a homogeneous material such as low steel. In this figure, let *A* be a vertical section of a cylinder provided with an accurately fitted plunger, *P*. The space, *B*, below this plunger, we will suppose to be filled with small, irregular fragments of lead, whose surfaces are covered with a coating of oxide of lead. If, now, sufficient force be applied to the plunger, *P*, the lead will be forced out of the hole in the lower end of the cylinder in the form of a rod, *C*, and every fragment of lead will have become more or less elongated, but will be prevented from actual metallic contact with adjacent fragments by a film or thread of oxide of lead. In this experiment, the elongated fragments of lead correspond to the extended compound crystals of iron before named, and the oxide of lead occupies the same relative position in the rod of lead as the "cinder" in a bar of wrought iron. If, now, in place of the fragments of lead, we place in the space, *B*, a solid mass of that metal, then, on applying adequate force to the plunger, *P*, there will be forced through the hole in the bottom of the cylinder a rod of lead, whose structural difference from the former rod, made from the oxide-covered fragments, is closely allied to that subsisting between a bar of "low steel" and one made of the cinder-coated compound crystals of wrought iron.

All steel in our day (save the comparatively unimportant product called blister steel) is made by some process involving melting and casting; and, although the various methods

employed all practically free the metal from an admixture of "cinder," and in consequence tend, so far as the elimination of cinder is concerned, to produce a homogeneous crystalline structure; still, owing to defects inherent in the method of casting—and oftentimes in the chemical constitution of the metal itself—the ingots of steel are too often far from homogeneous. In fact, their structure may be such that, when hammered or rolled, the resulting bar, although destitute of cinder, may, nevertheless, show evidences of fiber.

I will endeavor to explain how this appearance is produced. If we break a large ingot of mild steel (say from 12 to 15 inches square) at right angles to its length, and examine the fracture, we shall find, at a distance of from $\frac{3}{4}$ inch

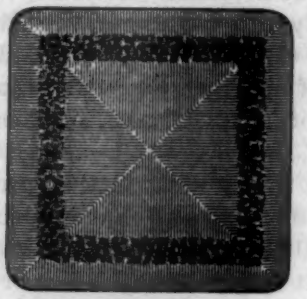


FIG. 5.

to 2 inches from its sides, a collection of cavities or "blow-holes" (as they are commonly called), which are of an irregular spheroidal form, and of variable size, the largest seldom exceeding $\frac{1}{2}$ an inch in diameter. These holes are separated from one another by partition walls of irregular thickness, and in most instances are coated on their interior surfaces with films of a more or less iridescent oxide of iron. *Fig. 5* will serve to give an idea of such a fracture as has been described.

When such an ingot is forged or rolled into a bar, it is seldom or never subjected to a "welding heat;" hence, the "blow-holes," even if it were possible for their sides to come in close contact, would not weld and become as solid as the homogeneous parts of the ingot; but, as a matter of fact, the

sides of these cavities rarely do come in actual contact, for they are held apart by the presence of a gas or mixture of gases, of whose character and pressure I shall speak later.

The forging or rolling flattens the blow-holes and also extends them in the direction of the length of the bar, the division walls between the "blow-holes" being extended also, the effect being, when the "blow-holes" are numerous, to produce an apparent fibrous structure in the bar, and the more numerous the "blow-holes," the finer and more "silky" the fiber. In case the "blow-holes" are large, and the partitions between them comparatively thick, they will—when the ingot is drawn into a bar—form seams of variable length and depth, as they chanced to originate from larger or smaller holes.

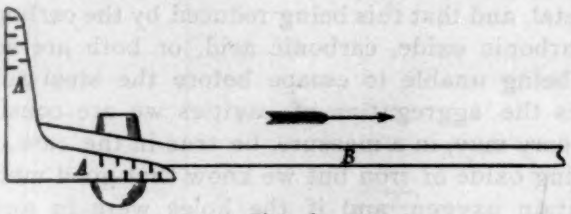


FIG. 6.

Such a state of structural affairs in a bar might not have much influence upon its ability to resist a tensile strain; but if such a bar were subjected to compression, it is easy to see that it would yield unequally, and much sooner on the side having the greatest number of such seams. But it is when such a bar is subjected to a transverse strain tending to pull it apart in a direction at right angles to its length, that these seams, whose progenitors were blow-holes, are the most injurious.

Take, for example, an "angle-iron" made from such an ingot. It is not at all improbable that the "seams" would be so arranged in the flanges (as at *A*, *A*, *Fig. 6*) as nearly to separate them into a series of rods held together transversely by occasional ligatures of metal. Now, if such a bar be punched or drilled through the "seams," and another bar, *B*, be riveted to it (as shown in the figure), and

the riveted structure be now subjected to a strain in the direction of the arrow, it is self-evident that the "angle-bar" would be much more likely to be pulled apart transversely through the rivet hole than if it were made of a homogeneous material.

There has been a great deal of speculation in regard to the origin of the array of "blow-holes" found in ingots of soft steel. Some have supposed that they were caused by gases dissolved in the fluid steel (very much as carbonic acid is dissolved in water), and that, at the moment of solidification, these gases separated from the mass of the metal, and arranged themselves in the order in which they are found, that of a hollow square (in the case of a square ingot), whose sides are parallel with those of the ingot. Others have asserted that oxide of iron is present in the fluid metal, and that this being reduced by the carbon in the steel, carbonic oxide, carbonic acid, or both are set free, which, being unable to escape before the steel solidifies, produces the aggregation of cavities we are considering. This theory may, in a measure, be true in the case of steel containing oxide of iron but we know that good metal does not contain oxygen, and if the holes were in any great degree due to the reaction mentioned, they would be likely to be uniformly distributed through the mass of the ingot, and not confined, as is the fact, to a well-defined zone; moreover, but a very small percentage (about 2 per cent.) of the gaseous contents of the blow-holes is found to be oxidized carbon.

Other suggestions, more or less occult, hypothetical, and ingenious chemical and molecular considerations, have been made; but all fail to account satisfactorily for the symmetrical arrangement of the "blow-holes" observed.

My own explanation of the formation and peculiar distribution of these cavities is a purely mechanical one, which I will now endeavor to make clear.

It is a well-known fact that a vertical stream of any liquid descending freely through the atmosphere drags along with it, by frictional contact, a notable quantity of the air, or of any other gas that may be in its immediate vicinity.

This fact, centuries ago, was taken advantage of in the construction of the blowing apparatus, called the "trompe," used for furnishing the blast for the forges of Catalonia.

This apparatus consists of a vertical pipe, *P* (usually of wood), whose height is determined by that of the head of water at the locality of the forge; the upper end of this pipe passes through the bottom of the wooden race-way, *R* (*Fig. 7*), and is closed or opened by the movable conical plug

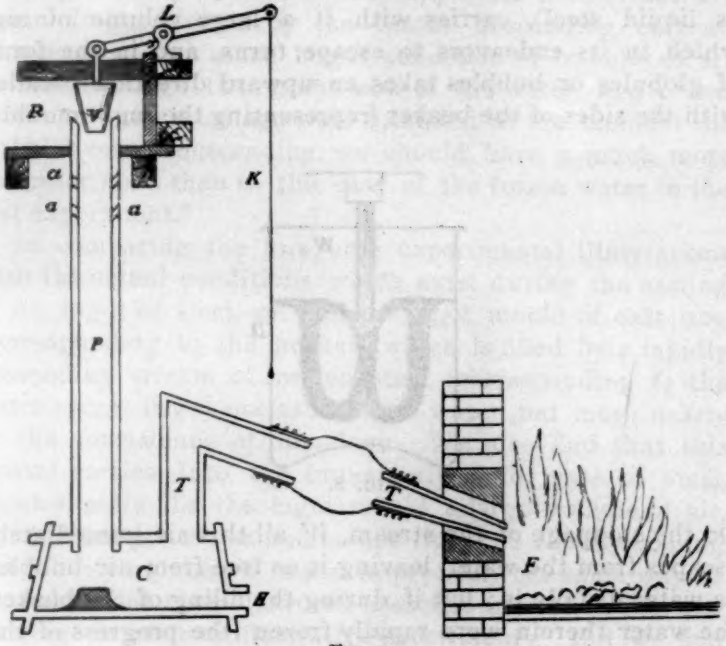


FIG. 7.

or valve, *V*. Below the bottom of the race-way, *R*, there are several inclined apertures, *a*, *a*, *a*, made in the sides of the pipe, *P*. These are for the purpose of admitting air, which, when the valve *V* is raised, is drawn in by the descending column of water, and, mixing therewith, is carried downward and discharged thereby into a receiving chamber, *C*. Here a separation of the air and water takes place, the former passing through the tuyere pipe, *T*, *T*, to the forge-fire *F*, the latter escaping from the receiving chamber

through a hole in its side at *H*. The volume and pressure of the blast supplied can be regulated within certain limits by raising or lowering the valve, *V*, by means of the cord, *K*, acting through the lever, *L*.

Now let us see how the principle of the "trompe" is concerned in the casting of an ingot of steel. Let the beaker, *B* (*Fig. 8*), represent an ingot mould, and the descending stream of water, *W*, a stream of molten steel. It will be seen that the stream *W* (for illustrative purposes regarded as liquid steel), carries with it a large volume of air, which, in its endeavors to escape, turns, and in the form of globules or bubbles takes an upward direction parallel with the sides of the beaker (representing the ingot mould).

FIG. 8.

On the stoppage of the stream, *W*, all this air immediately escapes from the water, leaving it as free from air bubbles as water usually is; but if, during the filling of the beaker, the water therein were rapidly frozen (the progress of the congelation being from the sides towards the center), it is evident that the ascending bubbles of air would be entangled in the ice as it formed, and we would have finally a vesicular mass or ingot of ice, quite similar, as regards its method of formation, to the ordinary ingot of steel.

Another illustration may make the formation of vesicles in steel ingots still more clear. If, in place of water in the preceding experiment, we substitute mucilage, or any other fluid of similar consistency, we approach much nearer

to the actual conditions which exist in the casting of a steel ingot; for the steel, as ordinarily melted, is never as fluid as water, but approximates more nearly in mobility to the character of mucilage. As, then, the stream of mucilage descends, it will be observed that it carries with it air, in the same manner as the stream of water; but that, owing to the viscosity of the fluid, the air bubbles rise through it more slowly and escape with greater difficulty, and that some of them, as they approach the surface, are again dragged down by the central descending current. Hence, there is a much larger collection of bubbles of air in the mucilage than there was in the water, and consequently, if the mucilage were solidified at the moment the bubbles ceased descending, we should have a much more vesicular mass than in the case of the frozen water in the last experiment.*

In comparing the foregoing experimental illustrations with the actual conditions which exist during the casting of an ingot of steel, we find an ingot mould of cast iron (corresponding to the beaker), which is filled by a rapidly descending stream of molten steel (corresponding to the water or mucilage), not as liquid as water, but more nearly of the consistency of mucilage. We also find that this stream carries into the imperfectly fluid mass of steel, which rapidly fills the ingot mould, a large volume of air, which attempts to rise and escape from the rapidly cooling and solidifying mass of metal in precisely the same way as the bubbles of air endeavored to escape from the water and mucilage in our two illustrative experiments. But we find another condition present in the case of the molten steel, that did not exist in either experiment, viz.: the fact of a high temperature in the fluid metal. If we examine this condition, we shall readily discover that it has a very important influence both on the size and number of the vesicles formed in the ingot of steel; for it is a well-known fact that dry air, for each 480° F. increment of temperature, increases its bulk by the amount of its original volume. Now,

* These experiments were shown to the audience by the lecturer.

as the fluid steel is at least of the temperature of 3,300° F., dry air introduced in the manner illustrated would be so expanded as to occupy seven times the space in the ingot that it did in the atmosphere.

There is, however, yet another fact that tends still further to augment both the size and number of the so-called "blow-holes" which we are considering. It is a well-known practical condition that the air in the immediate vicinity of steel casting pits is far from being dry. The large quantity of water used for cooling ingot moulds, and for other purposes, keeps the atmosphere surrounding both casting-ladle and ingot-mould in a very moist state, and it is certain that all such vapor-laden air carried into the molten steel would increase in volume for a given increment of temperature very much more than dry air, and would, therefore, correspondingly increase the size and number of the "blow-holes." Furthermore, this vapor of water does not act to this end altogether through its expansion under the influence of heat, for some, if not all of it, is decomposed by the high temperature, and its oxygen, together with that of the accompanying air, is absorbed by the walls of the cavities. This produces the iridescence observed, and leaves in the "blow-holes" an atmosphere composed mainly of hydrogen and nitrogen; and it is not at all improbable that in many cases this decomposition of the watery vapor does not take place until the steel is so far solidified as to prevent the walls of the cavities yielding to any great extent, and, under such circumstances, the gases named would be under a very considerable tension.

This view is confirmed by the investigations of Prof. F. C. G. Müller, of Brandenburg, who found that the mean composition of the gases in the "blow-holes" was:

	Per Cent.
Hydrogen	79
Nitrogen	19
Carbonic oxide	2
	100

and that their average pressure was 120 pounds per square inch. That under favoring conditions they may

have a much larger pressure is evident; and furthermore, that the sum of the pressures in all the "blow-holes" of any cross-section of an ingot of steel may originally be very considerable, and that after the cavities have been reduced in size by hammering or rolling, the sum of these pressures will be largely augmented.

Let us now examine the influence of these confined gases upon the steel after the ingot has been rolled into a bar, by considering a supposititious case—the most favorable one possible—and one not at all unlikely to occur in practice, as regards one or more blow-holes. We will suppose that we have an ingot of steel 15 inches square and 5 feet in length, and that this ingot has the usual zone of "blow-holes" grouped as before described, and that every cube of $\frac{1}{2}$ inch within this zone has a blow-hole within it, or 60,000 in the entire ingot, or 500 in any cross-section through the $\frac{1}{2}$-inch cubes. We will take, for our investigation, a spherical "blow-hole" $\frac{1}{4}$ inch in diameter, the area of whose largest cross-section is ·04908 of a square inch, and whose capacity is ·00818 of a cubic inch. If, now, our ingot be rolled down to a bar 1 inch square, it will be obvious that each side of this bar will be $\frac{1}{15}$ of that of the ingot, and that the area of its cross-section will be $(\frac{1}{15})^2$ or $\frac{1}{225}$ of the original cross-section of the ingot, and that the diameter of the $\frac{1}{4}$-inch "blow-hole" will have been reduced to $\frac{1}{15}$ of its original size, or

$$\frac{\cdot 25}{15} = \cdot 01666$$

of an inch, and the area of its cross-section will have become

$$\frac{\cdot 04908}{225} = \cdot 00021813$$

of a square inch. But if the original pressure of the gases in the blow-hole (120 pounds per square inch) be unchanged in the bar, their volume must remain unchanged, and this is only possible by a change of form in the "blow-hole" under the operation of rolling, from a sphere of $\frac{1}{4}$ inch diameter to a cylinder of ·01666 of an inch in diameter, and of sufficient

length to hold the original volume (·00818 of a cubic inch) of the gases. The length of such a cylinder will be

$$\frac{\cdot 00818}{\cdot 00021813} = 37\cdot 5$$

inches. But as the diameter of this cylinder is ·01666 of an inch, the area acted upon by the gases within it to tear it

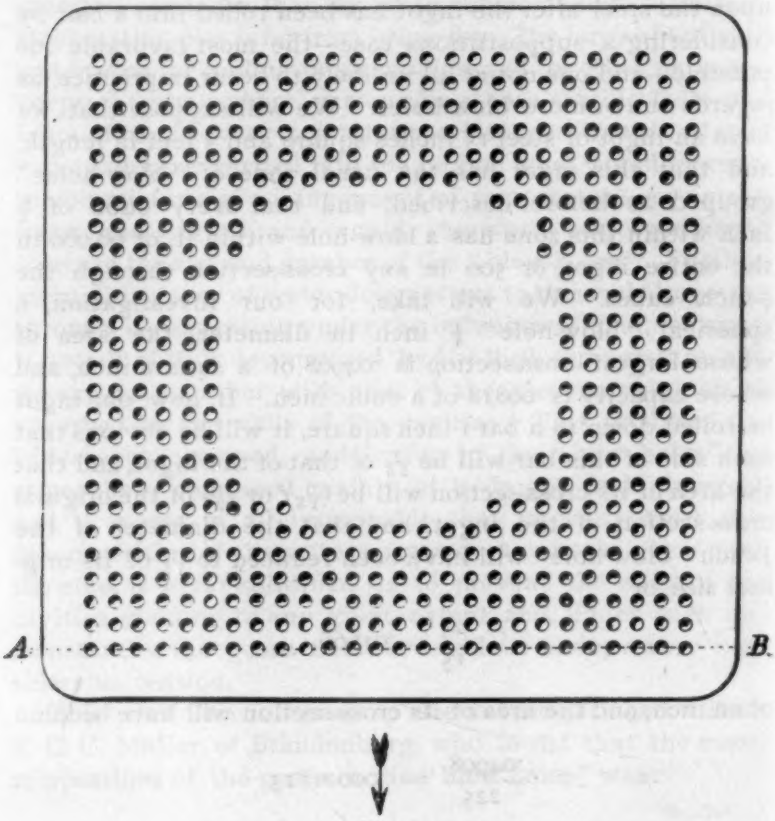


FIG. 9.

asunder longitudinally is equal to $37\cdot 5 \times \cdot 01666 = \cdot 62475$ of a square inch, and as by our supposition there are 500 holes in a cross-section of the ingot, we shall find at least 26 in the outside rows of the zone of blow-holes, and, therefore, we shall have in the 1-inch square bar the same number such

as we have described above; hence, the total area on which the pressure acts to effect the longitudinal disruption of the bar within the space of the length of one such row of cylinders is ·62475 × 26 = 16·25 square inches, which, multiplied by 120 pounds per square inch, gives us 1,950 pounds as the disruptive stress. To sustain this, we have what remains of solid metal in a section (of the length of the cylinders) made by a plane parallel to the side of the bar (corresponding in the bar to *A B* in the ingot, *Fig. 9*), and including the axes of the 26 cylinders above named, or 37·5 — 16·25 = 21·25 square inches. Dividing the disruptive stress by this, we have

$$\frac{1,950}{21·25} = 91·76$$

pounds per square inch. Now, let us compare the area on which pressure acts in the ingot with that on which it acts

FIG. 10.

FIG. 11.

in the bar. The area of the largest cross-section of a spherical "blow-hole" ¼ inch in diameter is ·04908 of a square inch, and we have shown that the area of a longitudinal-section of one of the above-named cylinders is ·62475 of a square inch, or 12·7 times the area of the cross-section of the original "blow-hole;" or, in other words, the process of rolling the ingot down to a bar 1 inch square, by transforming the original "blow-hole" from a sphere to a cylinder of equal volume, has multiplied the area upon which disruptive pressure acts 12·7 times.

The foregoing calculation is based upon the assumption that the twenty-six cylinders are arranged with their ends abreast (as per *Fig. 10*), which could only happen when the

"blow-holes" were symmetrically arranged in the ingot. It is also possible that these cylinders may be disposed as per *Fig. 11*, in which case there would be but half the number of cylinders within the area of 37·5 square inches, and the sum of the areas of their longitudinal-sections will be ·62475 × 13 = 8·125 square inches; which, multiplied by 120 pounds per square inch, gives us 975 pounds as the disruptive stress. To sustain this we have 37·5 — 8·125 = 29·375 square inches of metal, which is subjected to a strain of

$$\frac{975}{29{\cdot}375} = 33{\cdot}15$$

pounds per square inch.

There is still another arrangement of the cylinders which perhaps is more likely to occur than either of the others. (See *Fig. 12.*) By this the strain upon the metal will be between the figures given for that in *Figs. 10* and *11*, or about 65 pounds per square inch.

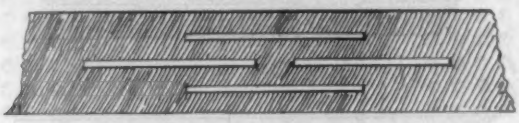


FIG. 12.

Now let us examine the disruptive stress on a transverse section of our 1-inch square bar. By our original supposition there must be in such a section 500 cylinders having an area of cross-section of ·00021813 each, or a total area of cavity of ·00021813 × 500 = ·109 of a square inch, which, multiplied by 120 pounds per square inch, gives us 13·08 pounds for the disruptive stress. To sustain this we have 1 — ·109 = ·891 of a square inch of metal, which is subjected to a strain of

$$\frac{13{\cdot}08}{{\cdot}891} = 14{\cdot}68$$

pounds per square inch.

It will be observed that the foregoing calculations have supposed that the volume and pressure of the gases remain unchanged under the operation of rolling or hammering,

which is the most favorable condition possible in the bar when "blow-holes" filled with gas are present in the ingot from which it is rolled. But it is not at all probable that so favorable a condition will uniformly be present in the bar; for it is much more likely that many of the cylinders will, under the stress of rolling or hammering, be more or less compressed, closed up, or shortened. For instance, if the diameter of one of these cylinders were reduced one-half, the pressure within the cylinder would become four times that of the initial pressure, or $120 \times 4 = 480$ pounds per square inch, which would act over an area of

$$37{\cdot}5 \times \frac{{\cdot}01666}{2} = \frac{{\cdot}62475}{2} = {\cdot}31237$$

of a square inch, and which, multiplied by 480 pounds, would give 150 pounds disruptive stress. If we suppose that there are 26 tubes thus reduced in diameter, we will have $150 \times 26 = 3{,}900$ pounds as the total disruptive stress on the whole number of tubes. To sustain this we have 37·5 square inches minus the sum of the areas of the longitudinal-section of 26 tubes (·31237 × 26), 8·12162 = 29·378 square inches; and dividing the total disruptive stress by this we have

$$\frac{3{,}900}{29{\cdot}378} = 132{\cdot}71$$

pounds per square inch of metal.

The pressures which these calculations show to be acting upon the metal under the supposed conditions are comparatively insignificant, but they are not unimportant, for they represent the probable minimum of the forces realized in practice, and, serving as indicators of the way such forces operate, they enable us to see clearly and appreciate fully the significance as applied to steel, of the homely old adage, "ye can tell from a little what a good deal means."

Now, after our study of the minimum possibilities arising from "blow-hole" compression and extension, let us see what would be the resultant pressure in case, by any accident of manufacture (I use this expression advisedly; for, whatever form or volume the cavities may assume, and

whatever pressure may ultimately be in them, these items are purely accidental and absolutely impossible of prediction or control), all of the 500 $\frac{1}{4}$-inch "blow-holes" in any cross-section of our 15-inch ingot are reduced by rolling it down to a 1-inch square bar, to $\frac{1}{15}$ of their diameter, still retaining their spherical form. In that event the diameter of the reduced spheres will be ·01666 of an inch, and the volume of each $\frac{1}{3375}$ of a sphere $\frac{1}{4}$ inch in diameter; and, as the pressure of a given weight of gas will be inversely as its volume, it follows that the pressure in these small spheres will be $3{,}375 \times 120 = 405{,}000$ pounds per square inch; and as by our supposition there are 500 "blow-holes," each having an area of cross-section of ·00021813 of a square inch, or a total area exposed to pressure of $·00021813 \times 500 = ·109$ of a square inch, and this, multiplied by 405,000 pounds per square inch, gives us 44,145 pounds as the total disruptive stress. To sustain this, we have the solid metal in the cross-section of the 1-inch bar. This we have found to be ·891 of a square inch, which is subjected to a strain of

$$\frac{44{,}145}{·819} = 49{,}545$$

pounds per square inch, a strain beyond the elastic limit of most soft steels—a limit of strain which permanently weakens the metal.

The foregoing calculations represent the maximum and minimum possibilities of disruptive pressure which may exist under the supposed conditions; but it is possible that the blow-holes may be larger and more numerous than we have supposed, and that the initial pressure may be more than 120 pounds—all conditions tending to augment the disruptive strain in the final shape given to the steel.

We have frequently heard of instances of the failure of steel plates, which, when subjected to chemical and physical investigation, seem to possess every quality essential for the use to which they had been put. The carbon is found to be in proper quantity; silicon, manganese, phosphorus and sulphur are not present in objectionable proportions; nevertheless, the plate has failed; and hitherto

there has been no satisfactory explanation for this anomalous state of affairs; but if it be admitted that at the point of rupture there may have been a string of blow-holes heavily charged with compressed gases, it is easy to understand that the plate or bar would be much more liable to fail at the point of rupture than where such blow-holes did not exist; at the same time, the metal on either side and in the immediate vicinity of the rupture may be found to have all desirable qualities, and as the rupture destroyed its own cause, no evidence of its existence would appear under any test which could be applied.

I think I have submitted evidence enough to show that the presence of blow-holes in soft steel is a constant source of danger, and that there is no certainty of a sound forging being made from an ingot containing them. It is, therefore, self-evident that the only way to secure sound forgings, bars and plates is to get rid of the blow-holes. Various suggestions have, from time to time, been made for accomplishing this. The chemical means thus far proposed confer properties upon the metal quite as objectionable as the difficulty they were designed to obviate. Some years since, the late Sir Joseph Whitworth proposed and practically carried out a mechanical process of compressing steel in the ingot mould while it was still fluid or plastic, his intention being to destroy the "blow-holes" by the action of the enormous pressure employed. He certainly succeeded in turning out from his works most admirable products in steel; but I have always had a feeling that the high character of his forgings was due more (much more in fact) to the chemical constitution of the metal, and its having been skilfully treated and carefully worked, than to any qualities resulting from its having been compressed while in a fluid state.

Let us examine this matter a little more closely. Suppose *I*, *Fig. 17*, to be a vertical section of an ingot mould filled with fluid steel, *S* (having more or less numerous "blow-holes" distributed through its mass, as indicated by the small circles), which may be forcibly acted upon by the plunger, *P*. Now, as fluids under pressure act equally in all

directions, it is evident that all the "blow-holes" will be reduced in size, and also that the tension of their contained gases will be increased in the inverse proportion to their reduction in volume; but it is not so clear that there is any action that will cause their removal from the steel altogether; in fact, it is not consistent with any known law of physics that a body pressed equally in all directions in a fluid should move at all; the tendency of such pressure would manifestly be to compress the body.

Now let us see what would be the force tending to rupture our supposititious ingot transversely before it has been subjected to compression. The area of the largest cross-section of a spherical blow-hole, $\frac{1}{4}$ inch in diameter, is 0·04908 of a square inch, which, as it is acted upon by a pressure of 120 pounds per square inch, will be subject to a total pressure of $0{\cdot}04908 \times 120 = 5{\cdot}88$ pounds; but as there are 500 such holes in any cross-section of the ingot, we have for the total transverse disruptive pressure on such a section $5{\cdot}88 \times 500 = 2{,}940$ pounds, which has, of course, to be resisted by the solid metal in the cross-section, which is equal to $15 \times 15 = 225 - (0{\cdot}04908 \times 500 = 24{\cdot}5) = 200{\cdot}5$ square inches, and, on dividing the total pressure by this, we have

$$\frac{2{,}940}{200{\cdot}5} = 14{\cdot}5$$

pounds per square inch on the metal.

Now, let us ascertain what will be the transverse disruptive force if the original "blow-holes" are reduced to one-half their diameter by compressing the molten steel. The area of the largest cross-section of a sphere $\frac{1}{8}$ inch in diameter is 0·01227 of a square inch, which will be acted upon by a pressure of $120 \times 8 = 960$ pounds per square inch, or $0{\cdot}01227 \times 960 = 11{\cdot}78$ pounds, which, multiplied by 500, gives 5,890 pounds of total disruptive strain, which is resisted by the solid metal in the cross-section, or 225 square inches $-$ ($0{\cdot}01227 \times 500 = 6{\cdot}13$ square inches) $= 218{\cdot}87$ square inches of solid metal. Dividing the total pressure, 5,890 pounds, by this, we have a pressure of 26·91 pounds per square inch upon the metal. Thus we see that by the com-

pression of the "blow-holes" to one-half their diameter, the strain which the metal is called upon to resist is increased 78 per cent.

It will, doubtless, be urged that the compressed steel is found to be actually stronger than that not so treated. This is true; but there is no evidence to show that this increment of strength is due to the closing up or removal of the blow-holes; on the contrary, we have shown that the metal is called upon to resist a greater strain per square inch after than before the compression, and if there were no other change in the metal save that due to the reduction of the size of the "blow-holes," it must necessarily be less able to resist tensile strain after than before compression. It is probable that the observed increase of strength after compression is entirely due to the forcing of the molecules of the metal into more intimate contact; for it is a well-known fact

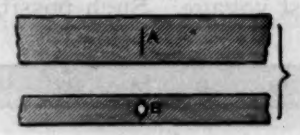


FIG. 13.

that the strength of both iron and steel is augmented by forging, and fluid compression of steel must be regarded as a species of forging.

I now desire to call your attention to a species of cavity —much too frequent in forgings of steel—that does not originate in the manner already described. If a large cold ingot be put into a furnace too highly heated, its exterior surface will expand so much faster than the parts at or near its axis as to strain the metal in the interior of the ingot beyond its elastic limit, and oftentimes actually to rupture its central continuity, as is shown at *A* in *Fig. 13*. Such a breach may, in some cases, have a diameter equal to half that of the ingot.

An ingot thus internally fractured, if hammered or rolled down to a smaller section, will have a cavity developed in the center of its mass, as shown at *B*, and, unless the existence of this cavity is discovered, serious difficulty may

result from the use of such a forging as a part of any mechanism. It is not at all impossible for a number of such cavities to be formed in the same ingot, if the heating be sufficiently rapid, in which case the initial rupture would occur at *A*, *Fig. 14*, at or near the center of the ingot; a second and third fracture would then take place almost simultaneously at *B*, *B*, about half way between *A* and the two ends of the ingot; and, finally, a third set of internal breaks may be formed at the points *C*, *C*, *C*, *C*, thus dividing the ingot into eight nearly equal parts of solid metal. The diameters of the several ruptures would vary in the following order, viz.: That at *A* would be the largest, those at *B*, *B* somewhat less, and those at *C*, *C*, *C*, *C* least of all. Such an ingot—if the internal ruptures were not too large—might be forged into a propeller shaft and actually put into a vessel without the defects being discovered until it was twisted asunder on its first voyage. Such possibilities of careless-

FIG. 14.

ness in the manufacture of heavy forgings of steel as I have described, make it highly desirable that some method be devised to detect the presence of such internal ruptures before much time and labor have been expended upon the forging, and also to prove its soundness when completed. Nearly thirty years ago a plan for this purpose was proposed by Mr. S. M. Saxby, R.N., and some extended experiments to test its practical value were made by direction of the Admiralty. But although the early investigations were very promising, the method has not become established as one of the acknowledged reliable means of testing forgings of iron or steel.*

It is possible that some method of electrical examination may be found of service in testing the soundness of forg-

* This method is described in an article first printed in *The Engineer*, December 7, 1867, reprinted in *Engineering*, December 13, 1867, and subsequently embodied in Kohn's "Treatise on Iron and Steel," 1869.

ings, and I will venture to suggest the following: Let *A*, *Fig. 15*, be an internal rupture in the ingot, *I*, to the extremities of which are connected the wires, *P*, *N*, of the battery, *B*, having in the circuit a galvanometer, *G*. Under these conditions the galvanometer needle will be deflected a certain amount, which is a function of the strength of the current and the resistance of the circuit; and if by any means the resistance of the circuit be diminished, the deflection of the needle of the galvanometer will be increased. For instance, if, in the proposed apparatus, the wire, *N*, be moved toward the left, for each inch of movement there will be a corresponding increase of deflection of the needle; but when the wire passes a point opposite the rupture, *A*, the law of the increase of deflection will suddenly change, and a considerable increase of deflection of the galvanometer will be noted, thus indicating the presence of an internal breach of continuity in the ingot or forging under examination.

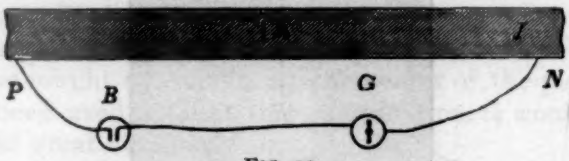


FIG. 15.

Thus far I have spoken only of the transverse internal rupture of steel ingots in consequence of too rapid heating; but longitudinal internal ruptures can be, and too often are, produced by the same cause.

In *Fig. 16*, let *A*, *B*, *C*, *D*, represent a cross-section of a steel ingot. If too rapidly heated, the opposing sides, *A*, *B* and *C*, *D*, will expand so much faster than the center that an internal rupture, *E*, *F*, may be formed; and the expansion of the sides, *A*, *C* and *B*, *D*, may in like manner develop a similar rupture, *G*, *H*, located in a plane at, or nearly at, right angles with that already named.

Such ruptures, though generally situated in planes at, or nearly at, right angles to one another, are not confined to planes so situated; for the planes of rupture may coincide with the diagonal planes of the ingot, or may occupy any

position between such diagonal planes and that shown in the figure. In fact, their position is fixed by the resultant action of two forces, due to the expansion of the exterior of the ingot by the sudden heating, modified by the powerful internal strains existing in the cold ingot, and tending to separate the metal at its center. These strains were established at the time the metal originally solidified in the ingot mould, and are occasioned by the outside of the ingot cooling while its interior was either fluid or plastic; and as the whole mass becomes cold, its interior, by the force of cooling contraction, is strained in many cases beyond its limit of elasticity, which limit may, with propriety, be defined as the beginning of rupture. An ingot of steel thus inter-

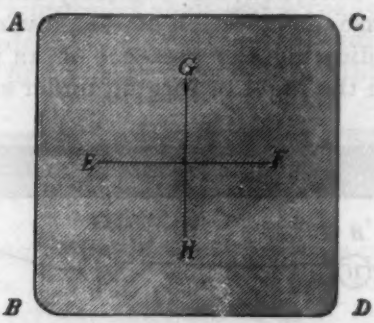


FIG. 16.

nally strained would require merely the small addition to the tension which a too rapid heating of its outside would furnish, to produce such interior longitudinal fractures as have been described. The extent of the influence of such internal strains in all stages of the manufacture of steel is very irregular and uncertain, and this fact makes them all the more worthy of consideration in all cases in which steel is to be subjected to uses which involve the application of sudden and violent shocks.

It is not at all improbable that in many instances ingots are ruptured internally, both transversely and longitudinally, thus aggravating the evil of either single species of rupture. If such an ingot were forged into a heavy crank-pin, its whole interior would abound with most irregular

and intricate imperfections, although at the same time the ends and cylindrical surface of the forging might have every appearance of soundness.

As a practical illustration of this, I cannot do better than quote the description of a defective forging given by Prof. Thomas Egleston in the *Transactions* of the American Society of Mechanical Engineers, Vol. VII, p. 263. He says: "I have recently had occasion to examine a forged crank-pin, made with great care from the best of open-hearth steel. It was rough turned to 16⅜ inches. To ascertain its quality in the center, a 1½-inch hole was bored through it. This hole revealed so large a number of cracks and cavities that the hole was increased to 4 inches, in the hope of cutting them out. Defects of considerable size were still found. The pin was then sawn in two (planed apart longitudinally) when single horizontal cracks 10 inches long and ⅜ inch wide were found, and inclined ones 7½ inches in length, in which were cavities ½ inch wide, to say nothing of defects of minor importance.

"None of these defects would have been revealed but for the forethought of examining the center of the piece. If it had been used without this examination, it would have produced great disaster."

I also have had an opportunity of examining the forging described by Professor Egleston, and was told that it was made by one of the oldest and most experienced manufacturers of such work in this country. My experience teaches me that such defective forgings are far more common than the managers of our steel works and forges are disposed to admit or even believe.

It is a common opinion that one of the reasons why steel forgings are often found hollow in their interior is the failure to work them under a sufficiently heavy hammer; but no hammer, not even "the hammer of Thor," can do more than aggravate the evil of internal ruptures in ingots of steel.

In treating of the influence of confined gases under pressure in the blow-holes of steel ingots, I have only thus far considered the case of gases at ordinary temperatures;

but if the ingot were heated to 1,000° F. (a dull red), the pressures would be three times as great as they originally were; that is to say, the original pressure of 120 pounds would become 360 pounds per square inch; and it is self-evident that this increased pressure will not tend to augment the strength or soundness of manufactured steel.

From what has been said, it will justly be inferred that perfect homogeneity is absolutely essential to the trustworthiness of steel. Forgings made from ingots containing

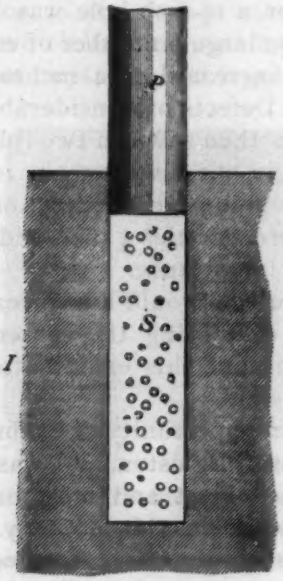


FIG. 17.

blow-holes must always be objects of suspicion. In gun forgings and armor-plate, solidity and soundness of structure are especially necessary.

It seems to the last degree absurd to spend labor and treasure in filling an armor-plate with thousands of magazines of force, every one of which is loaded with compressed gases, ready and anxious to contribute to its destruction. Such a condition is of material assistance to the penetration of shot, and is largely, if not wholly, responsible for the

failure of such plates as are not found satisfactory under fire.

What confidence can be placed in gun forgings made from material honey-combed with imperfections?

Steel containing gas-filled vesicles is especially objectionable in case the use to which it is put requires that it be hardened. On this point the experience of some eminent experts in the employment of steel will be of interest.

Of the effect of internal strains in steel used for the construction of cannon, Col. Eardley Maitland, R.A., Assoc. Inst. C. E., superintendent of the Royal Gun Factory at Woolwich, in a paper published about ten years ago, said: "On a review of the results obtained, the author, having seen so many instances of the fracture of steel, sometimes spontaneous and sometimes under stresses quite inadequate to produce the result, was of the opinion that internal strain was the gun-maker's worst enemy, and that it was a question of great moment whether it was worth while to incur the risk of setting up such strain by oil-hardening." If the distinguished author had said, instead of "setting up," augmenting "such strains," he would more nearly have described what actually occurs in hardening steel.

In the discussion of a paper communicated to the American Society of Mechanical Engineers, by Prof. John E. Sweet,* Mr. Henry R. Towne, President of the Yale & Towne Manufacturing Company, speaks of numerous unsuccessful attempts to harden certain castings of steel, and states that it was finally discovered "that the steel hardened beautifully *inside*, but that there was on the outside a thin skin of metal, about $\frac{3}{100}$ to $\frac{4}{100}$ inch in thickness, which, except by the cyanide process, did not harden at all. In all of the castings there was perfect hardening under this skin; and finally, the moral of this is that we should *look below the surface*"—a moral, I will add, which should not be forgotten by those who hope to succeed in the employment of steel.

* "The Unexpected Which Often Happens," *Trans. Am. Soc. Mechanical Engineers*, Vol. VII, pp. 156 to 160.

In the same discussion, Mr. Geo. M. Bond, Superintendent Gauge Department, Pratt & Whitney Manufacturing Company, said: "We had occasion to make a set of gauges in which the sizes were all $\frac{2}{10000}$ of an inch larger than the nominal sizes, and, five days after the gauges were finished, one of them suddenly gave way in the center, a crack extending around it spirally, but not so as to injure the ends of the gauge. Out of curiosity, I thought that I would measure the uninjured part to see whether any change had come in the diameter, and I found at both ends the diameter had enlarged 40 divisions of the micrometer, which is equal to $\frac{6}{10000}$ of an inch, and which, as magnified, represented a space to the eye of about $\frac{3}{16}$ inch under the microscope. This shows, I think, that if steel hardens at all, the internal strain must be something tremendous."

Prof. William A. Rogers, at that time Assistant Professor of Astronomy in Harvard University, in the same discussion, said: "The unexpected has *always* happened to me in this matter of obtaining hardened steel which has a homogeneous temper throughout the entire mass. The nearest approach to an even temper which I have ever been able to obtain has been at the works of Miller, Metcalf & Co., of Pittsburgh, and of Brown & Sharpe, of Providence. A short time since, I asked the latter firm to set a price upon a hollow steel cylinder 6 inches in diameter, 3 feet in length, having walls $\frac{1}{2}$ inch in thickness, hardened and ground on the outside only.

"The price which was set, from $300 to $500 without guarantee against flaws, may be taken as the estimate of the extreme uncertainty always attending any difficult case of tempering, held by those who have a full comprehension of the difficulty of the problem. The difficulty of giving a homogeneous temper is so great, according to my experience, that it is never perfectly done. The test which I apply as the gauge of an even temper is a very severe one. If all the lines ruled upon a highly polished bar of tempered steel have the same appearance, the temper of the graduated surface is good. I have, however, never yet seen a set of graduations in which the diamond has, with a constant pres-

sure, cut all the lines to the same depth. The diamond acting upon this polished surface detects the lack of homogeneity in the most perfect manner. If there is any person in this country, or in the world for that matter, who can temper a bar of steel 3 feet in length and for a depth of even ¼ inch, at any price, I should be glad to make his acquaintance."

Mr. George Ede, in that chapter of his work on "The Management of Steel" (edition of 1866) descriptive of the method of "toughening of steel in oil," as at that time practised "in the Gun Factories' Department of Her Majesty's Royal Arsenal, Woolwich," says, relative to hardening solid steel shot: "Thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally."

In this matter of hardening steel, the value of the "personal equation" of the workman is very important. It is not uncommon to find a practical mechanic who usually has good success in the use of a certain kind of steel with which his neighbors, equally skilful perhaps in other matters, can do nothing. So often have I encountered this fact, that I am inclined to believe that if a person in pursuit of information as to the proper quality of steel to use for any given article should travel through this land and obtain the honest opinions of all who were making the article in question, "the last state of that man would be worse than the first;" for the chances are that every person consulted would have an opinion differing from those of his fellow-craftsmen; and, although when our traveler started on his search for technical wisdom he was positive that he knew nothing, he could not rejoice in even that negative certainty when he returned. In the present state of our knowledge, there is no recognized uniform, scientific method of hardening and tempering steel; all we have is a tentative art, as crude in its development as it is obscure in its origin.

After thus discussing the defects of the ordinary method of manufacturing steel, I may be asked how these defects are to be overcome.

I answer, not by removing them, but by preventing the development of their causes—"blow-holes" and internal ruptures. The first can be prevented by casting the steel in a vacuum; that is to say, by exhausting the interior of the ingot mould and allowing the stream of molten steel to fall into it, without the possibility of its dragging air along with it. The second can only be avoided by careful heating of ingots which contain no gas-filled blow-holes.

Eternal vigilance is the price of excellence!

NOTES AND COMMENTS.*

MOLECULAR ANNEALING.

The Committee on Science and the Arts of the Franklin Institute is now engaged in the investigation of the interesting observation announced by Mr. A. E. Outerbridge, Jr., chemist to the Wm. Sellers Company, that cast iron, under the influence of repeated shocks or blows, gains notably in strength.

The announcement of this fact was made by Mr. Outerbridge, at the recent Pittsburgh meeting of the American Institute of Mining Engineers, as the result of experimental demonstration extending over a period of several years.

The facts, noticed apparently for the first time by Mr. Outerbridge, are directly opposed to the old and universally accepted notion that cast iron crystallizes and weakens under shock or continued vibration, and his announcement has naturally attracted an unusual amount of attention in the technical press.

One of the most intelligent criticisms of Mr. Outerbridge's work appears in the editorial columns of the *Scientific American*, from which we reproduce the following abstract:

Mr. Outerbridge noticed some years ago that "chilled cast-iron car-wheels rarely cracked in ordinary service after having been used for any considerable time; if wheels did not crack when comparatively new, they usually lasted until worn out or condemned for other causes." Although this curious fact was noticed, its real explanation was not discovered at the time, the cracking of new wheels being attributed to imperfect annealing in the oven.

In 1894, he had occasion to test some cast-iron bars for the Sellers Company. Before testing, they were placed in a tumbling barrel to be cleaned, and when they came to be broken in the transverse testing machine he

* From the Secretary's monthly reports.

"noticed with surprise that the average strength of the entire series was considerably higher than was usual with similar iron mixtures." A careful inquiry was made to ascertain the cause of the difference; but it was found that the machine was in good order and that the metal was of normal composition. The next step in the investigation was to cast twelve bars from one pattern and one runner. Six of these were cleaned by the tumbler and six with a wire brush. Upon breaking the twelve bars in the machine, it was found that those which had been subjected to four hours' incessant concussion in the tumbler were 10 to 15 per cent. stronger than the other bars! Various explanations were offered and proved by experiment to be false, until Mr. Outerbridge suggested that the increase of strength might be due to the "mobility of molecules of cast iron at ordinary temperature when subjected to repeated shocks." This theory was tested by subjecting each of six new cast-iron bars to 3,000 taps with a hammer upon one end. When they were broken in the machine they showed the same increase of strength as the bars that had been cleaned in the tumbler. He reasonably concluded that he had proved his case, and the engineering world is certainly indebted to him for the discovery of a most remarkable property of cast iron.

Mr. Outerbridge claims that while it is very well known that the annealing of castings increases their strength by releasing the strains set up in cooling, it is not known that "the molecules of cast iron are capable of movement (for they do not touch each other) without the necessity of heating the castings, and they can thus re-arrange themselves in comfortable relation to their neighbors and relieve the overcrowding near the surface of the casting; or, in more technical words, a molecular annealing may be accomplished at ordinary temperatures, which will release the strains in the castings, precisely as does annealing by slow cooling in heated pits or ovens."

In addition to the transverse tests already enumerated, a series of impact experiments by means of a falling weight was carried out.

"Six of the 1-inch square test bars, cleaned with the wire brush, were broken upon the impact machine by dropping the weight from a sufficient height to break each bar at the first blow; the six companion bars, also cleaned with the brush, were then in turn subjected to blows numbering from ten to fifty each of the same drop weight, falling one-half the former distance, these blows being insufficient to break the bars. The weight was then permitted to fall upon each of these bars in turn, from the height at which the six bars previously tested were broken on first blow. Not one bar broke. Two, three, six, ten, and in one case fifteen blows of the same drop, from the same extreme height, were required to break these bars. In another similar case the weight was dropped once from the former maximum height, then raised by inches until four more blows, each fall being 1 inch higher than the last, were delivered before breaking the piece. Subsequent tests gave still greater gains in strength."

It was pointed out that "molecular annealing" differed from annealing in the oven in that it cannot change the chemical constitution in any way; and it is merely claimed that "every iron casting when first made is under a condition of strain, due to difference in the rate of cooling of the metal near

the surface and that nearer the center, and also to difference of section; that it is possible and practicable to relieve these strains by tapping repeatedly the casting, thus permitting the individual metallic particles to rearrange themselves and assume a new condition of molecular equilibrium."

It is suggested, in conclusion, that all castings which are to be subjected to sudden and severe strains in actual service should never be tested at first up to anything like their full capacity. This applies to such castings as steam-hammer frames, housings for rolls, and possibly to cast steel and all metal castings. The influence of shock upon the various forms of castings other than iron is now being made the subject of experiment.

THE WELSBACH PATENTS IN THE ENGLISH COURTS.

The *Engineering and Mining Journal* gives the following *résumé* of the result of the recent litigation affecting the validity of the Welsbach patents:

After much delay, the actions in the English court by the Incandescent Gas Light Company against the De Mare Company and the Sunlight Incandescent Gas Light Company, for infringement of the Welsbach patents, were heard before Mr. Justice Wills, in the Queen's Bench division during the week ending April 18th. On the last-mentioned date the judge gave his decision in both actions, and briefly, before entering into details, we may say that the practical results are that the De Mare system is pronounced an infringement, while the Sunlight system is not. The patent on which the plaintiffs relied is that granted to Welsbach, and numbered 15,286, of 1885. In this patent the inventor claims the use of a mantle made by impregnating a fabric with the salts of the rare earths, ammoniating and igniting, so as to leave a skeleton of the oxides of the metals of the rare earths, the mantle thus formed having the property of glowing with an intense light when subjected to the heat of a gas flame. In the De Mare system the structure used is not a circular mantle, but is a plume or fringe of loose threads hung from a platinum wire and disposed in a plane, so as to be adapted for use in connection with an ordinary fishtail gas burner. The composition of the solution with which the threads were to be treated is, to all intents and purposes, identical with that used in the Welsbach system, but the threads after impregnation are not ammoniated, but ignited at once. In replying to the action, the De Mare Company put in many pleas attacking the validity of the Welsbach patent, but all of these failed miserably, so that their only point which could be considered worthy of attention was their claim that their plume or fringe was not a fabric such as was referred to in the Welsbach patent. In this case, also, the judge decided against them, as Welsbach specially states in his claim that the exact shape of the mantle shall depend on the nature of the flame to which it is to be applied.

The Sunlight Company relied on their patent, granted to Dellwik, according to which the fabric in the form of a mantle is treated with a solution of aluminum and zirconium salts, and afterward coated with a solution of chromium salt. In this way, after ignition, a mantle is obtained consisting of a structure of alumina and zirconia coated with chromic oxide. No mention

is made in the Dellwik patent of any rare earths, and as the use of such forms an essential point of Welsbach's patents, the Dellwik patent is not an infringement of the Welsbach.

It will be noted from the above judgments that the contention of the Incandescent Gas Light Company that the Welsbach patent covered the use of mantles made by igniting fabrics impregnated with the salts of any mineral substance that glows, quite falls to the ground. It is obvious that if the inventor had made such a claim it would have been invalid, as being an attempt to obtain protection for inventions which were not made at the time. Welsbach wisely confined his patent to such matters as he was sure of, and left it open to any one else to find other salts and oxides which would effect the same purpose. As Mr. Justice Wills remarked, it is the fate of a patentee who desires to obtain a perfectly valid patent to leave some loop-hole through which those following in his footsteps and emulating his success may creep in and share the rewards of his genius.

SCIENTIFIC BREVITIES.

Apropos to the lately discovered importance of *fluorescent substances*, the following directions for preparing the platino-cyanides will probably be of interest. The method is described by A. Schertel in the *Berichte*. Platinum chloride is precipitated by hydrogen sulphide at 60° to 70° C., and the well-washed platinum sulphide is dissolved in a warm solution of potassium cyanide. On evaporation, the potassium platino-cyanide ($K_2Pt(CN)_4$, $3H_2O$) crystallizes out, and equal parts of potassium sulphide and potassium thiocyanate remain in the mother-liquor. If a solution of barium cyanide be used, the barium platino-cyanide is obtained. With commercial potassium cyanide, containing large quantities of sodium cyanide, Schertel obtained the beautiful double salt ($KNaPt(CN)_4$, $3H_2O$) described by Martius.

Recent experiments have disclosed some important facts in reference to the toxic properties of the products of disintegration of animal tissue, which give rise to the phenomena of fatigue. It has been demonstrated that these are truly the effects of a species of *auto-poisoning*. Maggiori, Mosso, Wedensky, and others, find that, if the blood of a fatigued animal be injected into another animal that is fresh and unfatigued, all the phenomena of fatigue will be produced. Wedensky finds the poison to be similar to the deadly vegetable poison, curare. The poison engendered by fatigue is of the same chemical nature, and is as truly a deadly poison. In case it is created more rapidly than can be carried off by the blood, the organism suffers seriously.

The *Scientific American* has the following in reference to an extremely interesting series of experiments on the action of a powerful magnetic field on the cathodic rays in Crookes' or Hittorf's tubes, described by Herr Kr. Birkeland, in the *Elektroteknisk Tidsskrift*, Christiania. These experiments prove that in such a field the cathode rays are strongly deflected in the direction of the lines of force, and can even be concentrated upon the surface of the tube until the glass melts. Moreover, the evidence suggests that the rays

which emanate from one and the same cathode fall into groups, of which the physical constants are connected by some definite law, just as are the frequencies of the different tones emitted by a vibrating rod. The investigation has an important bearing on the theory of the aurora borealis. The Danish meteorologist, Herr A. Paulsen, is of opinion that the aurora owes its origin to phosphorescence of the air produced by cathodic rays in the upper strata of the atmosphere, and Herr Birkeland suggests that the earth's magnetism may be the cause of this phosphorescence becoming intensified in the neighborhood of the terrestrial poles.

PROPOSED EQUIPMENT OF THE NEW YORK SURFACE ROADS WITH COMPRESSED AIR MOTORS.

The Metropolitan Traction Company, which controls altogether about 132 miles of street railway in this city, and carries daily upward of 650,000 passengers, is contemplating an important change in the motive power of a large portion of its lines. About 32 miles of the system are at present operated as cable and underground trolley lines, and the plant is of the latest pattern and thoroughly up to date; but the greater part—fully 100 miles of the lines—is still worked by the slow and objectionable horse car. Several months ago the company determined to abolish the horse car and introduce in its place some form of mechanical traction, and, in the interval, its agents have been making an exhaustive examination of the many systems of street-car traction, which are being operated in Europe and America.

It has been determined to make a thorough trial of a compressed air motor, which has been designed by Joseph H. Hoadley, of the engineering firm of Hoadley Brothers, who is now associated with the American Wheelock Engine Company, of Worcester, Mass. We are informed by the Metropolitan Company that at a private trial recently had at the Worcester works, before the engineers and officials, the Hoadley motor showed a remarkable efficiency, as compared with any compressed-air motor which they had previously subjected to trial. At present, ten of the company's cars are being equipped with the new motor, and if they prove as successful in service as the experimental car which was recently tested, it is likely that all the existing horse-car roads will be similarly equipped.

The air will be carried in two cylindrical steel tanks, placed between the trucks and beneath the floor of the car, and they will be charged at an initial pressure of 2,000 pounds to the square inch. The power house at 147th Street and Lenox Avenue, will contain a 500 horse-power Greene-Wheelock engine and a Minerva air compressor, the reservoir capacity of the plant being 5,000 cubic feet. The compressed-air motor is being adopted in preference to trolley or cable traction, not merely from motives of economy, but also with a view of securing a service which shall be free from the interruptions to which the cable and trolley systems are liable.

The operation of these cars will be watched with close attention, not merely by the company which is making the experiment, but also by the engineering world at large. Engineers in the United States have been so fully

occupied with the development of electric traction—and it has had a growth and a success which is phenomenal—that comparatively little attention has been paid to other methods of traction which utilize the oil, gas, and compressed-air motor. As compared with the cost of the electric and cable systems, the compressed-air and gas motors, which are being increasingly used in European cities, are said to be showing remarkably economical results. Chief Engineer Pearson, of the Metropolitan Company, is now in Europe for the purpose of personally inspecting the working of some of the more important plants that are operated on the above systems.—*Scientific American.*

CONVERSION OF A TREE INTO A NEWSPAPER IN ONE HUNDRED AND FORTY-FIVE MINUTES.

The *Scientific American* quotes from the *Centralblatt für Oesterreich-ungarische Papier-industrie* the following account of a curious experiment:

A very interesting experiment was made on April 17th last at Messrs. Menzel & Co.'s paper and wood-pulp manufactory, at Elsenthal, in order to ascertain what was the shortest space of time in which it was possible to convert the wood of a standing tree into paper, and the latter into a journal ready for delivery. This experiment is of importance, because it shows what rapidity can be attained by the concurrence of practical machines and favorable conditions.

Three trees were felled in a forest near the establishment at thirty-five minutes past seven, in the presence of two of the owners of the manufactory and a notary, whom they had called upon to certify as to the authenticity of the experiment. These trees were carried to the manufactory, where they were cut into pieces 12 inches in length, which were then decorticated and split. The wood thus prepared was afterward raised by an elevator to the five defibrators of the works. The wood-pulp produced by these machines was then put into a vat, where it was mixed with the necessary materials. This process finished, the liquid pulp was sent to the paper machine. At thirty-four minutes past nine in the morning, the first sheet of paper was finished. The entire manufacture had thus consumed but one hour and fifty-nine minutes.

The owners of the manufactory, accompanied by the notary, then took a few of the sheets to a printing office situated at a distance of about 2½ miles from the works. At 10 o'clock, a copy of the printed journal was in the hands of the party; so that it had taken two hours and twenty-five minutes to convert the wood of a standing tree into a journal ready for delivery.

PAINTS FOR METALS.

Progressive Age prints the following abstract of some interesting researches on the value of paints for iron-work, made by Professor J. Spennrath, and recently published in the *Deutsche Bauzeitung*. As one result of these, Professor Spennrath concludes that none of the metallic oxides

commonly used combines chemically with linseed oil. The drying process depends exclusively on an absorption of oxygen by the oil, which is facilitated in a purely mechanical way by the presence of the pigment. The value of the different pigments used varies. Thus, zinc-white, when used for outside work, rapidly swells to double its previous volume, owing to the absorption of carbonic acid gas and water. Sulphuretted-hydrogen will cause red- or white-lead to act in a similar way; but, when pure, Professor Spennrath considers these latter two pigments satisfactory. Carbon paints are very stable, as is heavy-spar, but the covering power of the latter is small. In order to test the relative durability of various paints, sheets of zinc were coated with a number of different kinds. The zinc was then dissolved away by acid, leaving a film of paint. All these films, it was found, could be destroyed by the action of dilute nitric or hydrochloric acids, while the vapors of sulphuric and acetic acids acted similarly. Alkaline fluids and gases also destroyed the paints rapidly. Pure water was found to be more injurious than salt water, hence the destructive action of sea-water is to be attributed mainly to the mechanical effects of wash. Hot water was found to act more rapidly than cold. The most important discovery made was, however, the great influence of temperature. Films similar to those already described completely lost their elasticity, and became brittle when exposed to a temperature of 203° F. There was at the same time a large contraction. Similar effects are produced by prolonged exposure to considerably lower temperatures. Blistering he finds to be due to the inner coat of paint being so thick that it has not hardened thoroughly before the second coat is applied.

TECHNICAL NOTES.

M. Moisson is reported to have discovered *a substance harder than the diamond*, in the form of a compound of carbon and boron, produced by heating boracic acid and carbon in an electric furnace, at a temperature of 5,000°. This compound is black and not unlike graphite in appearance, and it appears likely to supersede diamonds for boring rocks, cutting glass, and other industrial purposes. It will even cut diamonds without difficulty, and it can be produced in pieces of any required size.

The question as to the *fusibility of platinum* in a carbon-heated furnace seems at last to have been definitely settled by Victor Meyer, says *Science*. A sheet of platinum, completely inclosed in a mass of fire-clay, was fused to a globule in a blast furnace heated with gas carbon. In this case, action of carbon or of furnace gases on the platinum was absolutely excluded. Under similar conditions, an alloy of platinum with 25 per cent. iridium was unchanged.

A curious phenomenon, first discovered by M. Charles Margot, was shown in a modified form by Professor Roberts-Austen at the recent meeting of the Society of Arts. An electric current was sent through an aluminum wire, raising it to a temperature of 400° above its melting point. Strange to say, it

did not fall, the film of the oxide on its surface holding it intact. In this condition it was attracted, owing to the current within it, by a magnet, and by careful manipulation could be made to tie itself into a knot.

Experiments recently made by the Royal Society of Belgium, in connection with the *welding of metallic bodies by simple pressure* at heats below their fusing points, have demonstrated the fact that the most perfect joints are obtained with gold, lead and tin, and the weakest with bismuth and antimony. In the course of the experiments, cylinders of pure metal, with smooth surfaces, were brought together by a hand-screw, and kept at a temperature of between 200° and 400° for from three to twelve hours. When separated, the break in no case corresponded with the jointed surfaces.

Soldering Glass by means of a metal solder has become a possibility through a recent discovery of an alloy, composed of 95 parts of tin and 5 of zinc, which melts at a low temperature and will firmly adhere to glass. Another alloy of tin and aluminum, containing 10 parts of the latter, melts at 390°, and can be used also for soldering glass. Either of these alloys can be cast upon glass without danger of breaking the glass if it has been previously heated slowly. Castings of these alloys made on glass become firmly adherent, as much so as though they were made on metal.

Nickel Plating of Wood.—Several methods are recommended for the first coating of metal; one of these, the Langbein dry process, consists in quickly pouring over the object a collodion solution of potassium iodide diluted with an equal volume of ether-alcohol, and when just about to set, the object is placed in a weak solution of silver nitrate in the dark; when a yellow color appears, the article is rinsed, exposed to sunlight and covered with copper. Wooden articles for surgical instruments may be treated by immersion in an ethereal solution of paraffin or wax, after which it is dusted with graphite or bronze powder.

Cryostase is a compound having the curious property of solidifying under the influence of heat and again becoming liquid at temperatures below the freezing point. It is the only substance which possesses the property of liquefying when cold and becoming solidified when hot; for although some substances, like albumen, harden at a moderately high temperature, they cannot be brought back to a liquid state even under the influence of a very low temperature. Full details of the composition are lacking. It is said to be made by mixing equal parts of phenol, camphor, and saponine, to which is added a slightly smaller quantity of turpentine.

Carbon Monosulphide.—Dr. Deninger, of Dresden, says the *Practical Engineer*, is reported to have prepared carbon monosulphide pure for the first time, and finds that, instead of being, as described in the text-books, an amorphous red solid, it is really a colorless gas. He prepared it by heating dry sodium sulphide with chloroform, or preferably iodoform, in sealed tubes, to 180° C., the gaseous products being made to bubble through aqueous caustic potash, which absorbed the sulphuretted-hydrogen, and the carbon

monosulphide passed through unabsorbed. By acting upon carbon disulphide with sodium, in the presence of some aniline, the new gas was also obtained. It is colorless, and easily condensable to a clear liquid, which evaporates rapidly and is extremely explosive.

The officials of the Mint Bureau express the opinion that the world's *gold production* for 1896 will equal the aggregate production of gold and silver prior to 1873. The *Iron Age* has the following to say on the subject:

The gold production of the world has been steadily climbing upward since 1890, when it stood at $118,849,700. The figures of 1892 were $146,815,100, of 1893 $57,287,600, and of 1894 $180,626,100. The figures for 1895 have not been fully verified by Director Preston, but a production of $203,000,000 is considered a conservative estimate. The production of 1896 is, of course, still a matter of conjecture, but the increases reported from nearly every country over 1895 are regarded as a safe basis for putting the production of the year at not less than $220,000,000. The United States is expected to show an increase this year from $47,000,000 in 1895 to $50,000,000. This is regarded as the lowest probable production, and $54,000,000 is considered a not improbable figure. This will keep the United States at the head of the gold-producing countries.

PUBLICATIONS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Borchers, W. Elektro-metallurgie. Part I. Braunschweig: Harold Bruhn. 1895. 8vo.

Manual of Guard Duty, United States Army. New York: *Army and Navy Journal*. 1893. 32mo.

Oesterreichische Ingenieur-und Architekten Verein. Bericht über Typen für Walzeisen Vienna, Society. 1892. 4to.

Omaha, Neb. Annual Report of the City Engineer for 1894.

Pennsylvania Coal Waste Commission Report. Philadelphia. 1893. 8vo.

Rhode Island State Board of Health. Appendix to the Seventeenth Annual Report. Report of the results obtained with Experimental Filters at the Pettaconset Pumping Station of the Providence Water Works. Providence: State Printers. 1896. 8vo.

Tuttle, Herbert B. Chemistry at a Glance. A Study in Molecular Architecture. No. 1. Oxides. New York. 1896. 8vo. Price, 60 cents.

U. S. Geological Survey. Production of Coal in 1892. By E. W. Parker. Extract from "Mineral Resources of the United States." Washington: Government Printing Office. 1893. 8vo.

University of Illinois: Catalogue, 1895–96. Urbana: University. 12mo.

Wheeler, Olin D. Sketches of Wonderland. St. Paul: Northern Pacific Railroad Company. 1895. 8vo. Price, 6 cents.

Report of the Tests of Metals and other materials for Industrial Purposes, made with the U. S. Testing Machine at the Watertown Arsenal, Mass., etc. Washington: Government Printing Office. 1895. I. W. Rielly, Major, Ordnance Department, U. S. A., Commanding.

BOOK NOTICES.

Compressed Air. Practical information upon air compression and the transmission and application of compressed air. By Frank Richards, Mem. A. S. M. E. New York: John Wiley & Sons. 1895.

The matter contained in this compact volume, of some 200 pages 12mo, has been revised and arranged in book-form from the author's contributions to the subject, which have appeared during the past two years in the pages of the *American Machinist*, where they attracted much favorable comment. The author is among those who believe that the capabilities of compressed air for power transmission and other useful applications have by no means been duly appreciated. His book gives much useful information on the subject and dispels many current errors. W.

Encyclopèdie scientifique des Aides-Mèmoire. Librarie Gauthier-Villars et Fils, Quai des Grands-Augustins, 55, a Paris. Price, francs 2.50 to 3 francs per volume.

Since our last notice of this publication, the following volumes have appeared. These are all published in uniform style, and each constitutes a volume complete in itself, encyclopædic in treatment, upon the subject to which it relates. No publication with which we are acquainted quite fills the place of this one, or so adequately meets the needs of one requiring a small yet comprehensive library covering all branches of applied science.

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint Cyr, aux Écoles des Mines et des Ponts et Chaussées et à l'École supérieure de guerre. *Attaque des Places.*

Lefèvre, Julien, Professeur à l'École des Sciences et à l'École de Médecine de Nantes. *La Spectrométrie. Appareils et mesures.*

Boursault, Henri, Chimiste à la Compagnie des Chemins de fer du Nord. *Calcul du temps de pose en Photographie.*

Gouilly, Al., Répétiteur à l'École Centrale. *Géométrie descriptive.* 3 vols

Lefèvre, Julien, Professeur à l'École des Sciences et à l'Ecole de Médecine de Nantes. *La Spectroscopie.*

Seguela, R., ancien Elève de l'École Polytechnique. *Les Tramways; voie matérielle.*

Moissan, H., et Ouvrard, L. *Le Nickel.*

Roads and Pavements in France. By Alfred Perkins Rockwell, A.M., Ph.B., formerly Professor of Mining at the Sheffield Scientific School and at the Massachusetts Institute of Technology. First edition. New York: John Wiley & Sons. 1896. Pp. 107, 12mo. Cloth, $1.25.

This manual of road-making gives, in concise form, the methods and practice in vogue in France for the construction, maintenance and repairs of highways in city and country, much of which could be followed with advantage in this country. The book is confined strictly to the practical details of the subject, and the illustrations (drawn approximately to scale) add notably to the usefulness of the text. The author acknowledges his indebtedness to several official publications of the French Government for the data presented.

The question of road improvement in this country is, happily, coming into greater prominence every year, and has already become a live question in every progressive community—in striking contrast with the public apathy of only a few years ago. Every contribution to the subject that gives useful information, therefore, should be welcomed. W.

Water Supply (considered principally from a sanitary standpoint). By William P. Mason, Professor of Chemistry, Rensselaer Polytechnic Institute. Mem. Am. Philo. Soc., Am. Chem. Soc., Am. Water Works Assoc., New England Water Works Assoc., Franklin Institute, etc. New York: John Wiley & Sons. 1896. Price, $5.

Professor Mason has laid the engineering fraternity and the water analyst under substantial obligations by his comprehensive and accurate *résumé* of the subject of water supply from the sanitary standpoint. In fact, the treatment of the subject is such as to satisfy the needs of all intelligent inquirers, professional and non-professional, to whom the question of a pure water supply has special interest.

The researches of the chemists and bacteriologists within the past decade or two have thrown a flood of light upon the causes and effects of water pollution, and have practically revolutionized the previously current ideas respecting preventive and curative methods. They have established, beyond the shadow of doubt, the direct and intimate connection between polluted water supplies and the prevalence of certain diseases (such as typhoid fever and cholera), and have demonstrated the fact that the spread of such diseases can effectually be checked by the adoption of certain simple preventive measures. They have demonstrated the vitally important proposition that it lies within the power of every municipality to secure, without excessive cost, a wholesome water supply.

All these matters are set forth with admirable clearness in the work under consideration. The author has taken pains to give references throughout his book to the sources of information, so that the reader desirous of making a more extended study of the subject will find his labor greatly lightened thereby. Professor Mason's work is a timely contribution to the most important sanitary problem of the day. W.

Cours de Physique de l'École Polytechnique. Par M. J. Jamin. Premier supplement, par M. Bouty. Paris: Gauthier-Villars et Fils. 1896. Prix, fcs. 3.50.

The volume above entitled is intended to supplement the "Cours de Physique" prepared by M. Jamin for the students of the École Polytechnique. It covers the subjects of heat, acoustics and optics, and incorporates the latest theoretical considerations in these important branches of physical science.

W.

The Forest Tree Planter's Manual. (Sixth edition.) By J. O. Barrett, Secretary of the State Forestry Association, Minneapolis, Minn. Minneapolis: Progressive Age Publishing Company. 1894.

This is an admirable, practical handbook of information relating to tree culture, issued by the State Forestry Association of Minnesota for free distribution. It could be imitated with advantage by similar associations in other States where the subjects of the preservation of the forest areas, and their artificial extension, have grown to be important questions. W.

A Dictionary of Chemical Solubilities. Inorganic. By Arthur Messinger Comey, Ph.D., formerly Professor of Chemistry, Tufts College. London and New York: Macmillan & Co. 1896. Price, $5.

Chemists have long felt the need of some reliable source of information on the subject of the solubilities, since almost the only accessible work of reference on the subject—that of Storer, which brings down the data to the year 1860—is practically antiquated, although still a classic contribution to scientific literature.

The present work seems to be all that could be desired by chemists, in respect of arrangement, comprehensiveness and accuracy. It will doubtless receive a warm welcome from the profession. W.

The Chronicle Fire Tables for 1896. A record of the fire losses in the United States, by States and Territories, during 1895, etc. New York: The Chronicle Company, Limited. 1896. Price, $5.

This statistical publication fully maintains, in the comprehensiveness and completeness of its fire data, the high standard of former years, and the position of the leading source of reliable information on these topics which we have cheerfully accorded it. In general arrangement the work follows the same plan as previous volumes.

The total fire losses for 1895 are given as $142,000,000, an increase of $2,000,000 over the figures of 1894. It is interesting to note that the *average* property losses, and also the *average* insurance losses, exhibit a decrease. This is a most encouraging factor in the situation, demonstrating increased care on the part of insurance companies, improvement in building construction and in the means and appliances for combatting fires.

These tables are simply indispensable to all who are interested in the subject of fire insurance. W.

Handbuch der chemischen Technologie. In Verbindung mit mehreren Gelehrten und Technickern bearbeitet von Dr. P. A. Bolley u. Dr. K. Birnbaum. Nach dem Tode des Herausgebers fortgesetzt von Dr. C. Engler. Die chemische Technologie der Brennstoffe. Von Prof. Dr. Ferdinand Fischer. Braunschweig: Vieveg u. Sohn. 1896. Preis, 5 mk.

The part above entitled of this standard publication relates specifically to the chemical technology of fuels. The subject is introduced by a general consideration of the thermo-chemistry of fuels, from which their thermal value must be calculated.

Following this, come chapters on the chemical and physical properties of wood, peat and mineral coal, with important historical and statistical data and elaborate tables, giving the constituents and fuel value of many of the European and American coals.

The part concludes with chapters on the formation of coal and the spontaneous combustion of coal.

The chemical engineer, familiar with the literature of his subject, will need no introduction to this thorough and comprehensive handbook, which ranks second in value to none in its special field. W.

A List of and Brief Guide to the Publications of the Pennsylvania Geological Survey. 1874–1895. Compiled by William A. Ingham, Secretary of the Board of Commissioners. Harrisburg: State Print. 1896.

The foregoing pamphlet embraces an alphabetical list of the numerous publications of the Second Geological Survey of Pennsylvania, supplemented by a topical index giving reference to specific subjects of local interest throughout the State. With the assistance of an index of this character, the labor of searching for information through the voluminous literature issued by the Survey is made comparatively easy, and the usefulness of these publications is substantially increased. W.

Weather and Disease. A curve history of their variations in recent years. By Alex. B. MacDowell, M.A., F.R.M.S. London: The Graphotore Co. 1895. Price, 2s. 6d.

The author, in this work, has given an array of statistical data bearing upon the presumable relationship of weather and disease, which, at the least, are strongly suggestive of an intimate connection as of cause and effect. His employment of the graphical method for the exposition and comparison of the data collected greatly simplifies their study, and he has certainly succeeded in exhibiting some new and instructive relationships heretofore unknown and unsuspected.

The field covered by the author is one in which much hypothesis and speculation have been indulged in, and he appears to have been the first to bring to bear upon it the careful method of analysis and comparison. In so far, therefore, his work is a valuable contribution to meteorological science. W.